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CONTENTS

Excavations in the Abbey Church of St.-Denis 1948. The Façade of Fulrad's Church. SUMNER MCKNIGHT CROSBY 347

Recent Exploration of the Infra-red Solar Spectrum at the McMath-Hulbert Observatory. ROBERT R. MCMATH and LEO GOLDBERG 362

The Portraits of Alexander the Great MARGARETE BIEBER 373

Heteroploidy in *Triturus torosus*. I. The Incidence of Spontaneous Variations in a "Natural Population." DONALD P. COSTELLO and CATHERINE HENLEY 428

Pre-Nineteenth Century Stage Irish and Welsh Pronunciation. J. O. BARTLEY and D. L. SIMS 439

The Genesis and Speed of the Telegraph Codes. FRANK G. HALSTEAD 448

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EXCAVATIONS IN THE ABBEY CHURCH OF ST.-DENIS 1948
THE FAÇADE OF FULRAD'S CHURCH

SUMNER McKNIGHT CROSBY

Associate Professor and Chairman, Department of the History of Art, Yale University

(*Read April 22, 1949*)

THE most recent excavations in the Abbey Church at St.-Denis in France were accomplished between June 24 and August 2, 1948 with the intention of completing the evidence acquired during the previous excavations begun in 1938 and 1939 and continued after the War in 1946 and 1947. The specific objective was to join the areas investigated in 1939 and in 1947 and to solve the riddle of the western façade of the eighth-century or Carolingian church. The particular fascination of archeology is that excavations often present new riddles rather than solutions to old ones. This is certainly true of the work in 1948 which uncovered positive, although fragmentary, remains of a western apse, or chapel, on the central axis of the Carolingian church built under the direction of the Abbot Fulrad and dedicated in the presence of Charlemagne and his court on February 24, 775. Before describing in detail the different types of masonry discovered, and on the basis of these remains, proposing hypothetical reconstructions of the plans for these important and interesting early medieval constructions, I should like to take this opportunity to express my sincere appreciation to the officers of the American Philosophical Society for their very generous grant, which enabled me to undertake the work. I should like to thank the Director of the *Monuments Historiques,* M. Perchet, and the members of the Committee on Excavations, for giving me permission once more to carry on these investigations. Without their interest and good-will and without the good-natured attitude of M. le Curé and those who with him maintain an active Parish in the midst of conflicting ideologies, the possibility of carrying on this unquestionably annoying type of research would indeed have been remote.

LOCATION OF EXCAVATIONS

The location of these excavations was extremely awkward for the celebration of the religious services, for we had to block off the entire northwestern section of the nave (fig. 1). In addition to reducing the available seating capacity almost fifty per cent, the constant shuttling of wheelbarrows full of dirt across the nave and south aisle to the outdoors, created more of a mess than a whole troup of muddy school boys. The holes are now covered by rough wooden planks, which are neither very sightly nor convenient, and it would be unreasonable and unsafe to attempt to extend the excavations within the church until a proper pavement has been reestablished. As a matter of fact, it is unlikely that further excavations will shed much light on the problems related to the western portions of the eighth-century building. Subsequent interments and rebuildings have either destroyed, altered or completely hidden parts of the masonry essential for a positive reconstruction of even the plan of the western ensemble. The presence, however, of a polygonal apse, or chapel, and the indications in documentary sources that there were also two small towers makes this early church at St.-Denis peculiarly significant in the development of medieval architecture. A detailed description of the different types of masonry uncovered will be necessary before we can propose possible solutions for the form of the façade, which may well provide another link in the evolution of the harmonic façades of later Gothic cathedrals.

EARLIER EXCAVATIONS IN THIS AREA

During the summer of 1939, when our first serious excavations were accomplished, two large openings were made in the south side-aisle and along the south side of the nave. A description of the masonry uncovered, which could be identified with Carolingian construction, is included in my first volume, *The Abbey of St.-Denis, 475–1122,* published by the Yale University Press in 1942. It is sufficient to recall that the location of the Carolingian façade was determined and that parallel walls projecting toward the north indicated a type of narthex or vestibule. The reconstruction of the façade proposed in my first volume was admittedly very hypothetical and several scholars have questioned its plausibility.

In 1946 a small opening was made in the north side-aisle. This was considerably enlarged in 1947 and a long trench was dug along the north side of the nave. Masonry similar to and in line with the walls discovered in 1939 was uncovered, but there was not enough time to excavate the central area of the nave. It was evident that the two excavations on each side of the nave would have to be joined if any reasonable solution for the early western ensemble was to be achieved and in spite of the obvious inconvenience to everyone concerned, permission was given to undertake the work. A barrier was erected down the center of the nave, blocking off the three western bays on the north side. This meant that wedding and funeral processions had to use the south side-aisle and these were not infrequent. One particularly busy Saturday we counted eight weddings, six funerals, and five baptisms. Surprisingly few objections came to my attention, although the inevitable questions of the curious visitor or local "amateur" were often difficult to answer.

PROCEDURE OF EXCAVATING AT ST.-DENIS

The initial step in excavating at St.-Denis, after receiving the necessary permissions, is perhaps the most difficult one. The existing marble pavement was laid down in the nineteenth century under Viollet-le-Duc's direction. It was intended to be permanent and was set in a bath of wet cement, which completely sealed the extremely fine joints. In order to raise the large marble slabs, which measured about five feet long by two feet wide and were only two to three inches thick, without breaking or chipping them, it was necessary to saw the joints by abrasion and to soak the area in water for two or three days. Under the pavement is a layer of extremely solid cement between eight and ten inches thick. This has to be broken up in much the same manner as tearing up a street, only we had no mechanical equipment. The noise of a compressed air hammer inside the church would probably have convinced the populace that the building really was to be demolished. Once the pavement and cement have been removed the problem of excavating is relatively simple, for the fill in most areas is a closely packed dirt debris for the most part of the nineteenth century, containing little or nothing of archeological interest. This obviates the necessity of careful screening, although a supervisor must be on hand as new areas are attacked to observe the character of the fill. The workmen, although untrained for this type of work, were usually attentive and careful. No large stones or masonry of any type were disturbed until a thorough investigation had been made. Although it is always preferable to excavate an area from the top down, at St.-Denis this was not always possible. In order not to interrupt circulation within the

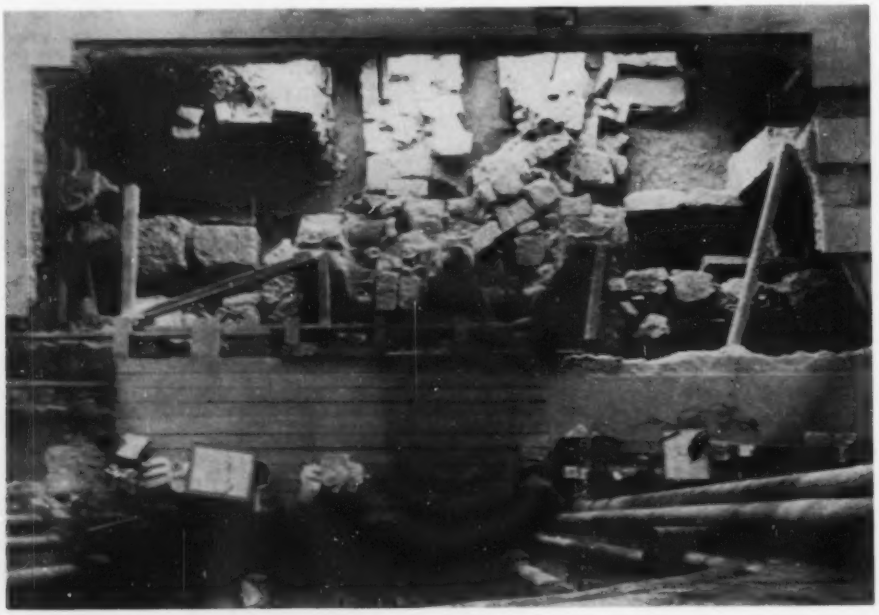

FIG. 1. General view of the nave excavations from above.

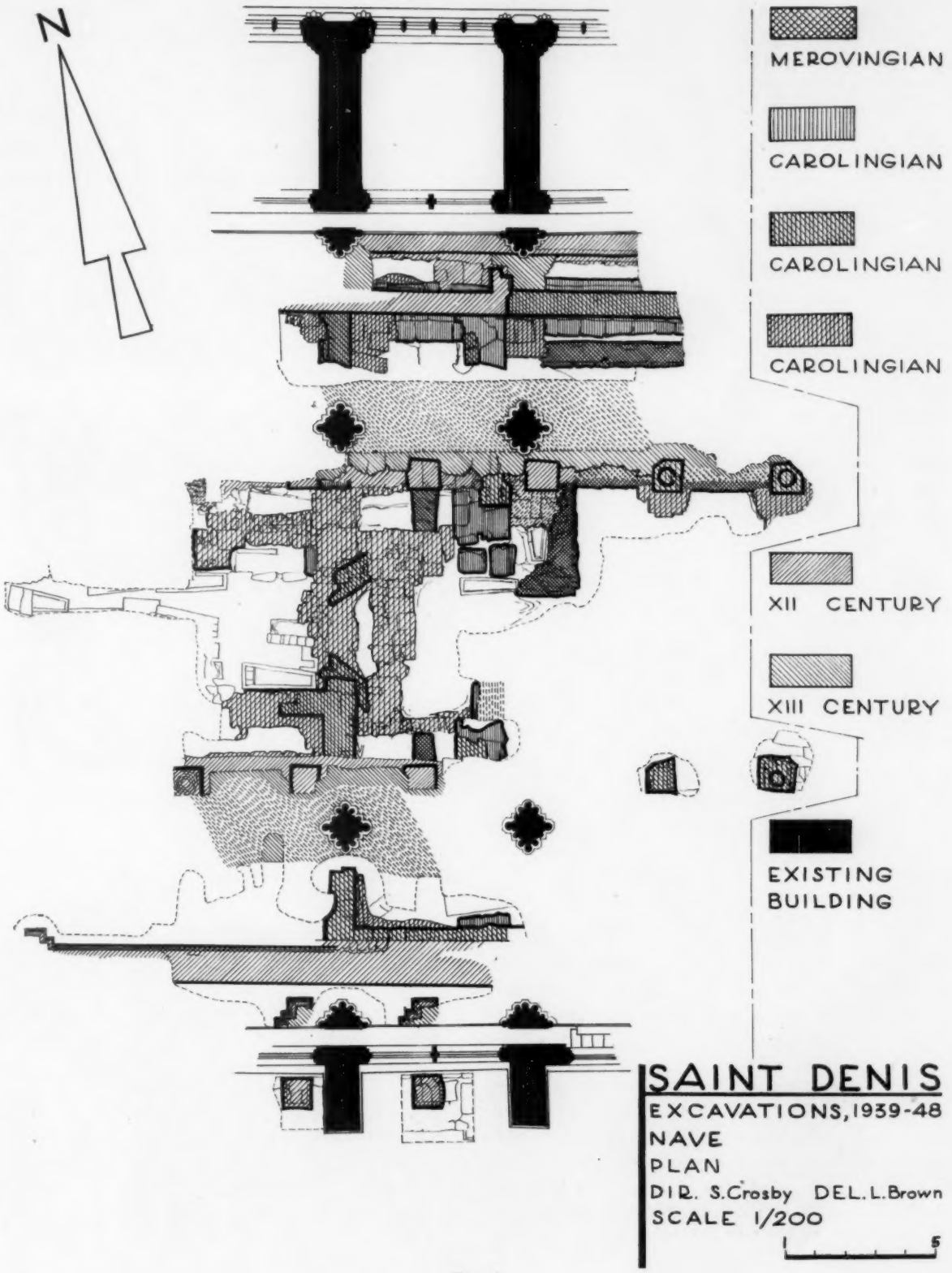
N
MEROVINGIAN
CAROLINGIAN
CAROLINGIAN
CAROLINGIAN
XII CENTURY
XIII CENTURY
EXISTING BUILDING
SAINT DENIS
EXCAVATIONS, 1939-48
NAVE
PLAN
DIR. S. Crosby DEL. L. Brown
SCALE 1/200
5

FIG. 2.

church any more than was absolutely essential, it was often necessary to dig tunnels under the pavement which then had to be shored by wooden props or masonry piers. A considerable area had to be investigated in this way in 1948 with consequent hindrances and difficulties.

COMPLEXITY OF MASONRY DISCOVERED

In discussing the results of these last excavations perhaps the most outstanding characteristic is the complexity and confusion of the masonry uncovered. In only one other small hole (on the north side of the central crossing) did we encounter so many burials, which had involved destruction of the early masonry; and nowhere else were we confronted with so many different types of masonry. At least six distinct modes of construction, usually employing different types of stone, can easily be identified (fig. 2). These different foundations and lower courses of wall construction intersect each other and in some cases are superimposed so that, even after long and minute investigation, it seems difficult to find an exact or reasonable explanation for the ensemble as a whole.

MEROVINGIAN MASONRY

Until the excavations of 1947 no masonry had been discovered that could reasonably be identified as pre-Carolingian. During that excavation a wall, or sub-structure for a wall, was found under the north side-aisle, running parallel but inside the massive construction accepted as being typical of the Carolingian building. This wall, only .70 metre wide, is very poorly built. Small irregular stones and a rough mortar create a type of heavy rubble, in which there are placed, at irregular intervals, relatively large blocks of lime. The fact that this wall rests on the solid subsoil, that it is located inside the Carolingian building, and that it apparently continues under the Carolingian masonry, certainly indicates that it is a vestige of an earlier construction. The presence of the lime blocks precludes the possibility of its being Gallo-Roman masonry,[1] and one is therefore forced to conclude that it dates from the Merovingian period. More extensive remains of a similar type of construction were identified during the 1948 work (fig. 3), which proves that buildings of some sort existed on the site before Abbot Fulrad began to erect the important Carolingian basilica. This masonry is indicated in figure 2 by cross-hatching.

LOCATION OF FIRST CHURCH AT ST.-DENIS

Those familiar with the history of St.-Denis will remember that there is contradictory evidence for the location of the first church dedicated to the Saint in this locality.[2] The documentary sources tend to indicate that the first building—a small chapel built about 475 at the instigation of Ste. Geneviève—was situated on the site of the present Eglise de St.-Denis, or St.-Denis-de-l'Estrée, at the end of the rue de la Republique, not far from the railroad station. Other texts, as well as

FIG. 3. Detail of pre-Carolingian foundations.

archeological evidence, support the thesis that this first building was near to, if not on, the same ground as that of the abbey church.[3] Although the few metres of Merovingian masonry[4] discovered during my excavations can be arranged to fit a pattern, or plan (fig. 4), not unlike the western

[1] I am indebted for this information to M. Georges Duval, who has been conducting the excavations of the Roman remains in the Cluny Museum, Paris, France; and who came to St.-Denis several times to examine this masonry carefully.

[2] For a discussion of this evidence see my first volume, *The Abbey of St.-Denis, 475–1122*, I: 67–70, New Haven, Yale Univ. Press, 1942.

[3] Excavations in 1947 directed by M. Jules Formigé, *Inspector Général des Monuments Historiques*, in the park just north of the abbey church, uncovered several plaster sarcophagi at different levels, the earliest of which could be dated in the seventh century. This proves that the Merovingian cemetery, located by the excavations between 1900 and 1905, extended to the south and were almost adjacent to the present abbey church.

[4] This masonry and its implications will be described in detail in the revised edition of my first volume, which is being prepared for a French translation.

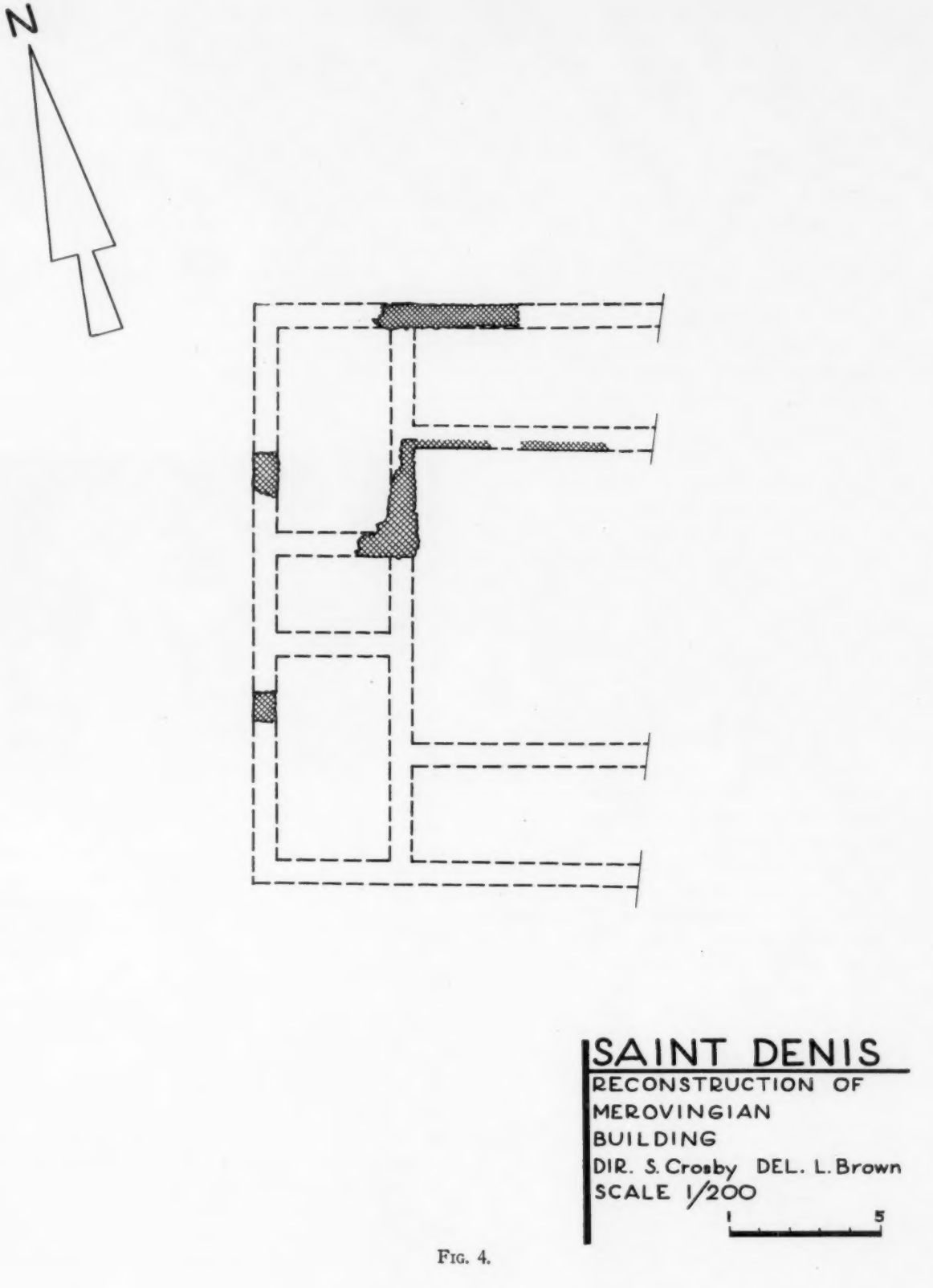
N
SAINT DENIS
RECONSTRUCTION OF
MEROVINGIAN
BUILDING
DIR. S. Crosby DEL. L. Brown
SCALE 1/200
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FIG. 4.

portions of the sixth-century church of St.-Etienne, on the site of Notre-Dame in Paris,[5] there is still insufficient evidence to prove that the first church erected in honor of Saint Denis was actually on this site. In any case these earliest foundations, even though they were evidently reemployed in some parts of the Carolingian construction,, do not shed any light on the form of the eighth-century façade, which is the real subject of this paper.

TWELFTH AND THIRTEENTH CENTURY FOUNDATIONS

There are two other types of masonry, included in the area excavated in 1948, that should be identified before entering upon a discussion of the Carolingian façade. These foundations today support the great piers of the existing nave arcade and obviously cannot be disturbed without danger to the present building. They cut across the Carolingian masonry from west to east and obscure completely the possibility of reconstructing the Carolingian plan in its entirety. Even if an attempt could be made to investigate, or tear apart, this solid mass of stone and mortar, it is unlikely that any positive indications for the eighth-century ensemble would be discovered, since the earlier masonry is apparently incorporated *in toto* in these later foundations. The only pertinent observation that needs to be made in this discussion is that these later foundations are easily distinguished from the other modes of construction, both by their location and by their form. They date from the twelfth and the thirteenth centuries.[6] Their surfaces are often rough and unfinished, being composed of varying sizes of stones, often reemployed from the earlier buildings, which are joined together into a solid mass by a very cohesive, strong mortar. The twelfth-century portions (right to left diagonal hatching, fig. 2) are in line with the bases and outside walls of the Carolingian nave. This construction, built to serve as a link joining Abbot Suger's new western entrance to the old Carolingian nave, necessitated the destruction of the eighth-century façade. The thirteenth-century foundations (left to right diagonal hatching, fig. 2) for the present nave used the twelfth-century masonry as a base and merely added to it under the piers where it was essential.

CAROLINGIAN MASONRY

Three other types of construction remain to be described and all three apparently belong to the eighth-century building. Two of them are immediately comparable to masonry which must be accepted as Carolingian, but the third type is quite distinct. The characteristic Carolingian foundations, at least those employed for the outer, or principal, walls, consist of large, roughly hewn blocks of soft limestone, often measuring 1.50 metres long by .60 metre wide and .70 metre high (vertical hatching, fig. 2). These *libages* were evidently cut directly from the quarry and

FIG. 5. Large stone *libages* of Carolingian foundations.

transported to the site, where they were rolled into position without too much attention to their precise alignment. Their immense size eliminated the need for mortar and the joints were merely filled with dirt or small stones (fig. 5). Wherever the Carolingian construction was discovered intact, that is to say where the foundations were found undisturbed with the actual lower courses of the walls resting on them, there were always three layers or levels of *libages*. Only one, the lowest level, was encountered during the 1948 excavations, although two levels exist in a few adjacent areas to be identified with the Carolingian western ensemble. One might say that these large, almost cyclopean, blocks are the hall-marks of Abbot Fulrad's building at St.-Denis. I have concluded that their presence, even though encompassed by other masonry, is an indication of this construc-

[5] Lenoir's plan, regarded with some suspicion today, is reproduced by J. Hubert, *L'Art Pré-Roman*, Les Editions d'Art et d'Histoire, fig. 104, Paris, 1938.

[6] A summary discussion of these foundations is given in my article, Fouilles exécutées récemment dans la basilique de Saint-Denis, *Bulletin Monumental*, 167–181, 1947. A more complete analysis will be included in volume II, *The Abbey of St.-Denis, 1122–1231*.

tion. Equally distinct as Carolingian masonry are the smaller, cut stones that formed the walls of the building (vertical with diagonal left to right hatching, fig. 2). They are of a similar limestone which, however, when exposed to the weather, often presents a different exterior finish and texture. These stones are placed in careful alignment and give the actual dimensions of the Carolingian building as well as its form (fig. 6). It is their presence in readily distinguishable, angular walls that proves the existence of the polygonal chapel under discussion. If these walls rested on the large *libages,* there would be no particular difficulty in explaining the construction, but, for no apparent reason, they are placed on a type of

FIG. 6. North side-aisle excavation of 1947 showing eighth century juncture with twelfth and thirteenth century masonry.

foundation that I have not as yet encountered in any of the other areas excavated.

This masonry consists of large, irregular stones of an indeterminate variety, which are extremely hard and as often as not show no marks of having been cut or fashioned by any tools (vertical with diagonal right to left hatching, fig. 2). The mortar is coarse, with a large quantity of sand, although the resulting masonry is stable, because of the weight of the stones employed. Curiously enough this particular type of foundation does not rest on the solid, clay subsoil. Ten to fifteen centimetres of black dirt exists between the bottom stones and the clay. Lacking any comparable foundations, it is obviously difficult to assign them a date. In the southeast corner of the excavation, however, a small area was uncovered, where it is apparent that this agglomerate masonry overlaps a *libage* of the Carolingian foundation. On this evidence and because of the fact that characteristic Carolingian wall construction exists on top of it, I have concluded that it formed part of an intermediate, or unexpected, addition to the original plan for the western façade (fig. 7).

If the reader has been able to comprehend this detailed examination of the different types of masonry, it may be possible for him to follow the reconstruction of the Carolingian plan I should now like to propose and to speculate as to its plausibility.

A plan of the three different types of Carolingian masonry (fig. 8) immediately establishes the fact that the western portion of Fulrad's Church was a complex construction. Although it is apparent that this construction included a type of narthex, or vestibule, in the center of which was a polygonal apse, it is difficult, indeed almost impossible, to reconstruct the plan in its entirety. I should like first to analyze the implications of the existing masonry and then to explain the hypothetical reconstruction (fig. 9), which I believe agrees with these implications.

For purposes of identification I shall refer to the entire western construction as the narthex and to the different walls according to the points of the compass; i.e., the inner or nave wall will be the east wall and the outer wall or façade proper will be the west wall.

NARTHEX NOT AN ADDITION

For certain reasons, such as the different thicknesses of the walls and a possible interpretation of a textural description which will be discussed shortly, it might be assumed that the narthex as a whole was an afterthought, extending beyond the heavy east or closing wall of the nave. The fact alone, however, that the great *libages* of the foundations continue uninterruptedly along the north side and are also found under the west wall (fig. 8) is proof, in my opinion, that the narthex was planned from the beginning and cannot be considered an addition.

CHANGES IN PLAN

There is definite evidence, though, that changes in the program took place, very likely while the construction was in progress. If the narthex was to be merely a terminal structure for the nave, or perhaps more correctly the normal means of en-

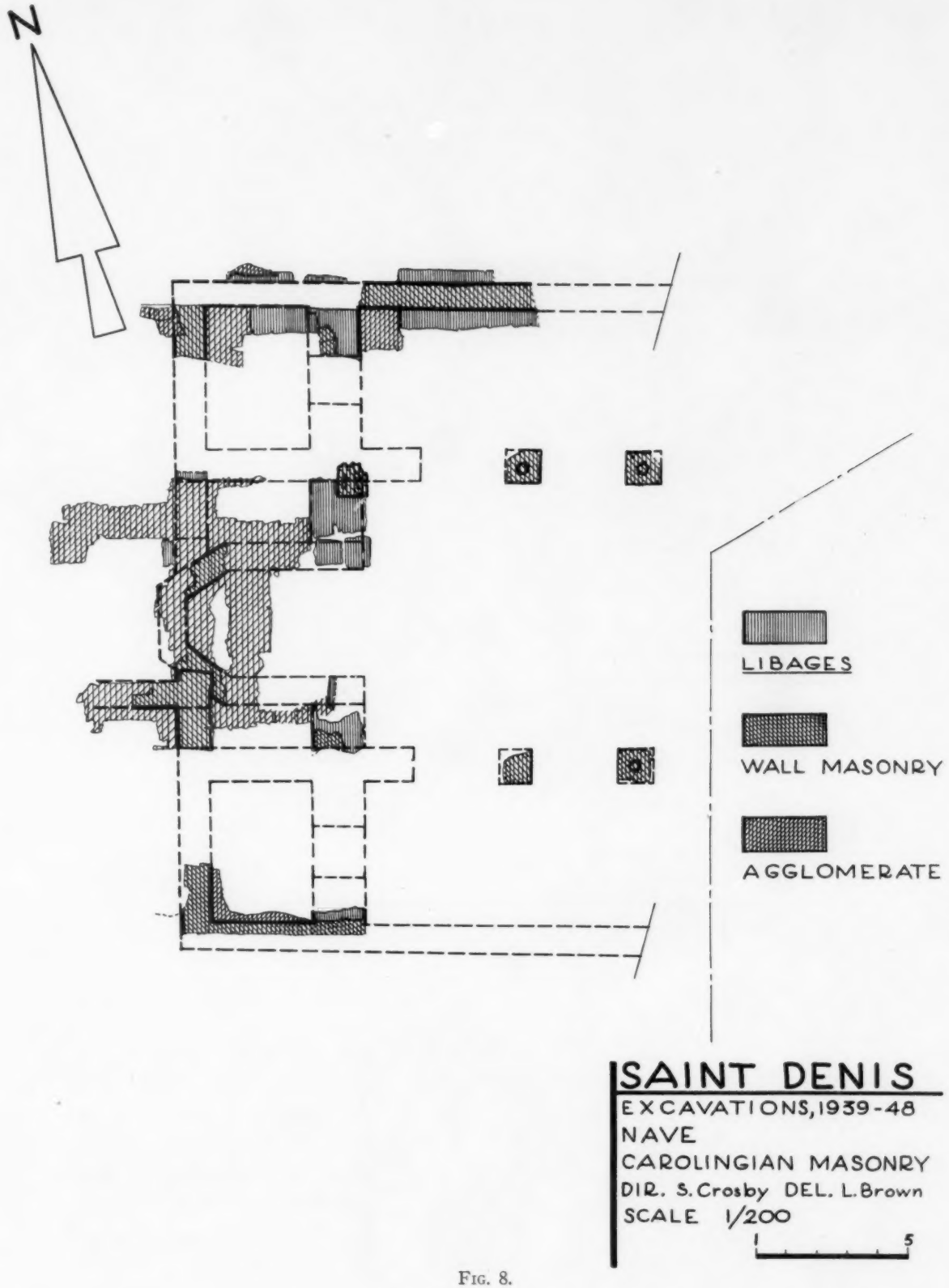
FIG. 7. Agglomerate masonry and angular walls of west apse.

tering the church, it is difficult to understand why different kinds of masonry were used in the foundations. The *libages* were certainly solid, strong foundations for any type of construction and one would think that a uniform system of masonry would have been used, unless for some reason additions or changes occurred in the planning for which less arduous substructures might have been considered adequate. The agglomerate foundations under the polygonal apse and placed against the corners of both the south and north ends would seem to be just such a type of added, or subsequent, construction. This agglomerate masonry has an irregular outline, although in many places, notably under the western projection of the apse and under what must have been the south wall of the apse, this masonry has been removed, or cut into, to make place for later burials or to supply materials for other constructions. It should also be noted that this agglomerate masonry seems to function as a solid mat foundation, rather than as regularly shaped substructures for specific walls. I have already mentioned that in one place at least this masonry overlaps a *libage* and therefore must belong to an intermediate campaign of building.

Perhaps the most striking evidence of a change in program exists in the masonry of the apse itself. As can be seen in the plan (figs. 2, 8) the angular southern wall of the apse has Carolingian wall masonry projecting over it in direct alignment with the west wall of the narthex and also projecting at almost right angles to the west. A possible explanation for this will be proposed shortly. It is sufficient at present to establish the fact that changes were made in the plan of the narthex evidently while it was under construction.

THICKNESS OF WALLS

Other interesting variations in the masonry of the narthex are the different thicknesses to be observed in the walls themselves. The normal thickness for the exterior Carolingian walls at St.-Denis is .90 metre, as can be seen in the portion of the north nave wall, which corresponds exactly with other sections of this wall found during the other excavations. The angular walls of the polygonal apse are likewise .90 metre in width. The west wall was apparently somewhat thicker, although no complete section of it was uncovered except in the projection over the apse masonry just mentioned. This measures 1.05 metres across, and a wall of this thickness seems to coincide with the other portions of Carolingian walls and foundations found to the north and south in the same alignment. A third width, this time much thicker, was evidently used for the east wall adjoining the nave. Once again no in-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LIBAGES
WALL MASONRY
AGGLOMERATE
SAINT DENIS
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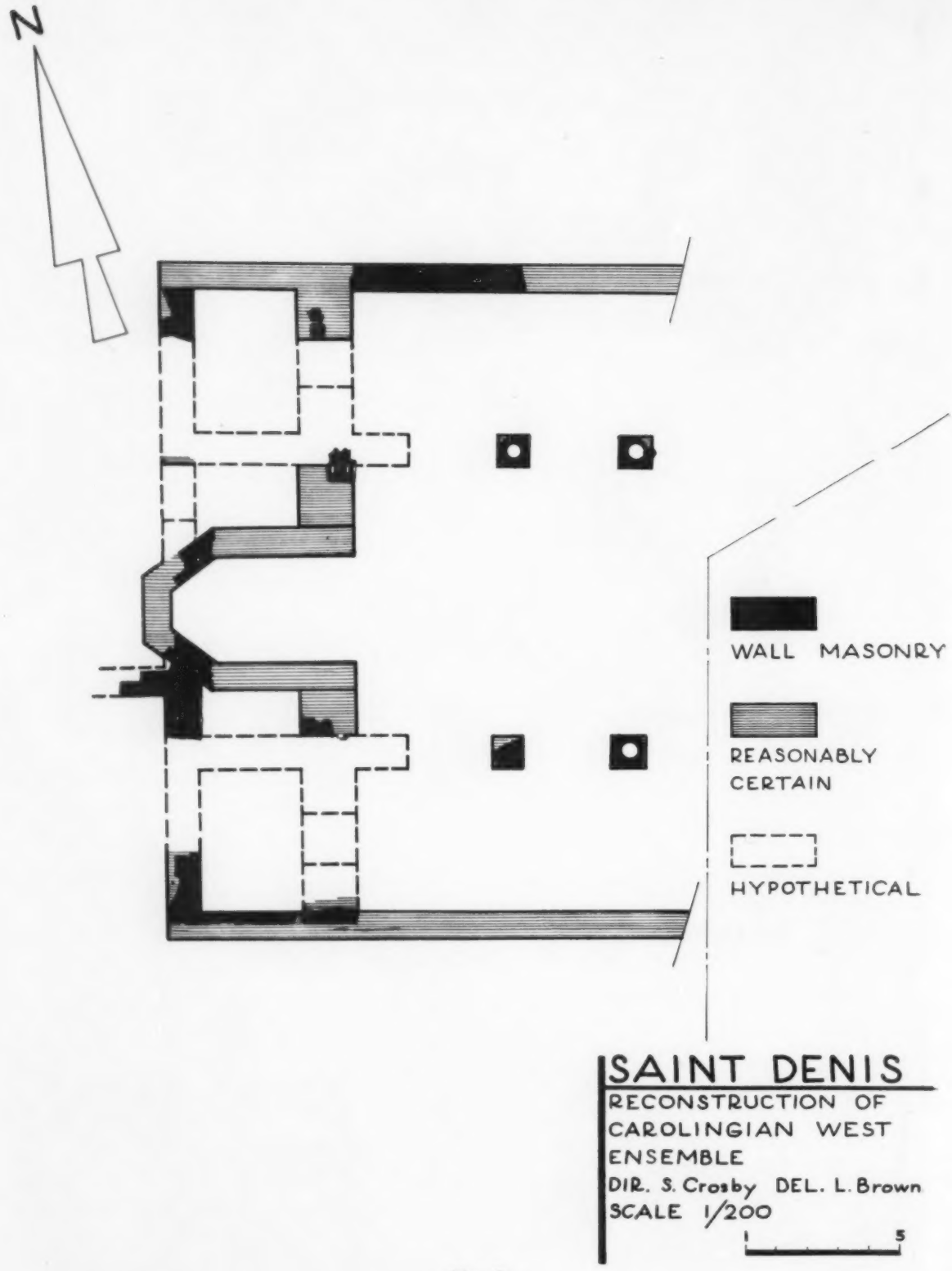
FIG. 8.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REASONABLY CERTAIN
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SAINT DENIS
RECONSTRUCTION OF CAROLINGIAN WEST ENSEMBLE
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FIG. 9.

tact portion of the wall was uncovered but there are finished surfaces to the north and south which are flush with the underlying *libages* indicating that this masonry extended to the outer limits of the foundations rather than being placed roughly in the center of the foundations as exemplified in the exterior nave walls. By continuing the lines of these finished surfaces a wall 1.80 metres thick results and this corresponds as well with the Carolingian foundations to the north and south.

FORM OF WALLS

The recurring Carolingian masonry in alignment with the west wall of the narthex presupposes that this was a continuous wall with possible openings for doors, which would be quite normal for the western façade of a building. The polygonal apse, as originally planned, projected slightly to the west breaking the plain surface of the façade.

The massive foundations of *libages* under the east wall, however, stop abruptly as they approach the central axis of the nave. It is therefore plausible to presume that an arched opening, approximately 3.60 metres wide, gave access to the apse from the nave. Although the foundations of this east wall also cease abruptly after projecting slightly from the exterior walls to the north and south, an examination of the masonry proves that it has been roughly cut away. It is consequently reasonable to assume that they originally formed a continuous foundation across the ends of the side-aisle. Whereas the almost totally demolished stone sarcophagus across the ends of the *libages* on the north side of the apse appears to have been placed there at an early date, the large complete stone sarcophagus across the south wall does not rest on the solid sub-soil and could have been placed there at almost any time.[7]

NARTHEX DOORWAY

There is one additional piece of masonry related to the east wall construction that has unusual significance. It is a large stone, 1.05 by 1.15 metres, situated on the *libages* north of the apse. First of all it is the only Carolingian masonry in the narthex, with the exception of the exterior north wall, that is at a high enough level to be related to the Carolingian pavement level. This level was definitely established by the discovery in 1947 of the four bases for the second bay of the eighth-century nave and of fragments of the Carolingian pavement *in situ*. This level is .75 metre below the surface of the existing pavement[8] and the stone in question is .90 metre below the present pavement. More significant, however, is the presence of two irregular oblong holes cut .25 metre into the thickness of the stone. These holes are so formed as to suggest that they served as sockets for the upright posts between which a door was hung.[9] The location of the stone and especially of the holes in direct alignment with the interior surfaces of the bases for the nave arcade makes it almost certain that a doorway existed at this point, which explains very neatly a twelfth-century text which has intrigued scholars for many years.

SUGER'S TEXTS

Since this text contains the most complete descriptions, available at this time,[10] of the Carolingian façade, this is perhaps the moment to quote it in full and to see in what measure it confirms or complicates the interpretation of the masonry under discussion. Two passages in Abbot Suger's writings, which give an account of the rebuilding of the Abbey in the twelfth century, refer specifically to the constructions at the west end of the Carolingian nave.[11]

[7] The large complete stone sarcophagus on the south side was the first one found during my excavations (1939) and caused considerable excitement. In the presence of an official from the Louvre, the broken lid was removed and the contents carefully examined. It had been previously opened and then refilled with hundreds of heterogeneous human bones. Although the manner of cutting stone was old, there was no available clue as to its date.

[8] This corrects the assumption made in my first volume that the Carolingian pavement level was 1.10 metres below the present pavement. Crosby, *The Abbey of St.-Denis, 475–1122*, I: 132.

[9] Similar holes were found in one of the lintels of the south transept doorway.

[10] Dr. J. J. Morper of Bamberg, Germany, has discovered a manuscript which, in his estimation, contains a description of the church at St.-Denis in the year 799. Although I have been in communication with Dr. Morper, I have no information about the manuscript itself nor of its contents, beyond a few meagre details, which will be mentioned in the ensuing discussion.

[11] For those unfamiliar with the chronology of the buildings at St.-Denis, it should be noted that the only changes to the Carolingian church between the eighth and the twelfth centuries were a small triple chapel added to the east of the apse in 832 and a tower, which fell down before it was completed, built with funds given to the Abbey by William the Conqueror late in the eleventh century. The location of this tower was ascertained in 1946 when eleventh-century foundations were discovered under the paving of the north transept—proof that the tower

Thus we began work at the former entrance with the doors. We tore down a certain addition asserted to have been made by Charlemagne on a very honorable occasion (for his father, the Emperor Pepin, had commanded that he be buried, for the sins of his father Charles Martel, outside at the entrance with the doors, face downward and not recumbent); and we set our hand to this part. As is evident we exerted ourselves incessantly with the enlargement of the body of the church as well as with the trebling of the entrance and the doors, and with the erection of high and noble towers.[12]

Since in the front part, toward the north, at the main entrance with the main doors, the narrow hall was squeezed in on either side by twin towers neither high nor very sturdy but threatening ruin, we began, with the help of God, strenuously to work on this part, having laid very strong material foundations for a straight nave and twin towers. . . .[13]

To recapitulate, these passages tell us that in the twelfth century what was believed to be an addition erected by Charlemagne in honor of his father, Pepin the Short, whose tomb was outside the entrance with the doors,[14] was demolished by Abbot Suger when he began his new church; the main entrance was *ab aquilone*, or "toward the north," and was a narrow hall squeezed in between small twin towers, which to twelfth-century eyes were neither very high nor sturdy; the Carolingian entrance contained several doors since they are always referred to in the plural; and in the twelfth century the entrance and doors were trebled when the existing western portions were built.

The positive evidence of my excavations proves that the twelfth-century demolitions included the whole Carolingian narthex. Not only are there well preserved twelfth-century walls extending from the present narthex to join the walls of the Carolingian nave, but the exact location of the bases for the columns of this "joining structure" is also evident. Both the walls and bases are found over the masonry of the Carolingian narthex continuing to a point where a juncture with the Carolingian nave itself could be established (fig. 2). The evidence of the Carolingian masonry has already been examined with the conclusion that the narthex was planned at the same time as the nave and was not, as a whole, an addition. It is, therefore, possible to suppose that Charlemagne did build some addition to the narthex and that by the twelfth century this addition was considered to be the entire narthex.

PEPIN'S TOMB

The exact location of Pepin the Short's tomb unfortunately was not established by the excavations.[15] Evidence of more than twenty burials were found within and adjacent to the narthex. Only a few of them appear in the plans published here, but there was a continuous line of sarcophagi along the exterior of the apse, most of which must have been comparatively late since the interments involved the removal of some of the foundation masonry. Although tombs were found on the central axis of the apse and in other locations, especially to the north, that might have been the main entrance, these in particular had been emp-

was erected in the corner between the north transept and the nave of the Carolingian church. Consequently the "front" part of the building (or west portions) torn down by Suger in the twelfth century must have been the Carolingian narthex.

[12] "Accessimus igitur ad priorem valvarum introitum; et deponentes augmentum quoddam, quod a Karolo Magno factum perhibebatur honesta satis occasione (quia pater suus Pipinus imperator extra in introitu valvarum pro peccatis patris sui Karoli Martelli prostratum se sepeliri, non supinum, fecerat), ibidem manum apposuimus; et, quemadmodum apparet, et in amplificatione corporis ecclesiae, et introitus et valvarum triplicatione, turrium altarum et honestarum erectione, instanter desudavimus." Suger, *De Administratione*, ch. XXV, ed. E. Panofsky, *Abbot Suger*, 44, Princeton Univ. Press, 1946. The translations are Dr. Panofsky's.

[13] "Quia igitur in anteriori parte, ab aquilone, principali ingressu principalium valvarum porticus artus hinc et inde gemellis, nec altis, nec aptis multum, sed minantibus ruinam, turribus angebatur, ea in parte inito directae testudinis et geminarum turrium robusto valde fundamento materiali." Suger, *De Consecratione*, ch. II, ed. E. Panofsky, *op. cit.*, 88.

[14] That this was the original position is confirmed by a letter from Louis the Pious to Abbot Hilduin of St.-Denis in 835, which quotes a similar passage from the inscription on the tomb itself. This reference adds the detail that the tomb was in front of the threshold, *ante limina*, of the basilica. For my earlier conclusions of the evidence of these texts and complete references to them see Crosby, *The Abbey of St.-Denis, 475–1122*, I: 93, 118–125.

[15] In 1812 a tomb was found in front of the central door of the existing, or twelfth-century, façade. This was immediately identified, with great enthusiasm, as Pepin's tomb, although nothing was discovered to support such a theory. In the light of our present knowledge of the location of the Carolingian façade such an identification is impossible. It is most likely that Pepin's tomb was opened in the twelfth century, if not before, and was moved at that time to the choir, where it apparently was when the Parisian mobs opened it during the Revolution. See R. Roy, *Histoire de la basilique et de l'abbaye de Saint-Denis*, 4, 46–47, Lille, 1861.

tied or completely disturbed at an earlier date. In fact, nothing was found, although the areas around each one and the contents of each coffin were carefully investigated and sifted, that could be used to identify the personages or even the dates of any of the burials.[16] The textual evidence stating that Pepin was buried "outside at the entrance with the doors" does not exclude the possibility that his tomb was within the narthex, i.e., outside the main body of the church. It should be noted, also, that the only burial, within the area covered by the apse, is indicated by the bottom remnants of a stone sarcophagus at the northeastern corner.

LOCATION OF ENTRANCE DOOR

The reference in the texts to the situation of the main entrance *ab aquilone* or "toward the north" has given rise to many speculations. Most scholars have concluded that the entrance must have been on the north side of the nave,[17] but Professor Panofsky, in an ingenious manner, has demonstrated how the text itself could be interpreted to mean the west end of the church as opposed to the east end.[18] The discovery of the stone with holes for door posts, indicating that a door existed just north of the apse, opening from the narthex into the nave, explains the text in a simple manner. The main entrance was through a "narrow" hall—narrow indeed for it was probably only about 2.00 metres wide—on the north side of the apse. A similar entrance probably existed along the south side, but it must have been restricted to the monks and gave access either to the cloisters or other claustral buildings on the south side of the church and would not, therefore, have been mentioned as a main entrance.

The projection to the west of Carolingian masonry, overlying the apse masonry on the south side, is difficult to explain. At first I believed it to be the foundations for a porch added by Charlemagne to protect the tomb of his father, Pepin the Short. The fact that there are no indications of similar masonry on the north side of the apse and also that the main entrance was not on the axis of the nave leads me to suppose that this masonry, keyed into the angular walls of the apse, served as part of a wall or corridor for the monks' use only, shutting them off from the public as they moved to and from the claustral buildings.

TWIN TOWERS

The next problem is the two relatively low towers that "squeezed in the narrow entrance hall." Perhaps the greatest disappointment of the 1948 excavation is that they did not solve this problem. The twelfth- and thirteenth-century foundations crossing the Carolingian narthex, as already indicated, make it impossible to excavate these crucial areas. One might suppose that such towers would have risen above the north and south extremities of the narthex; and that, if they were slightly rectangular, as a reconstruction of the plan (fig. 9) would seem to indicate, they might well have given the impression of "squeezing" or confining the narrow entrance. Indeed the fact that the entrance is described as a "narrow hall" would indicate that a wall, opposite the apse wall did exist, as shown in the reconstructed plan. Such walls could have served as bases for towers in conjunction with the other walls of the narthex.

There is, however, a conflicting piece of evidence. In a very summary account of a recent report by Dr. J. J. Morper in Germany, it is stated that a description of Fulrad's church in 799 fails to mention any western towers.[19] Admittedly it is difficult to evaluate such evidence without more complete information about the manuscript and its contents. But, if it is true that no towers were present on the west façade of Fulrad's church in 799, it is still possible that they could have formed part of the Carolingian building as the addition made by Charlemagne—an addition that was an integral part of the narthex, but which was not completed until the early years of the ninth century. The towers were certainly present in the twelfth century and were

[16] A few intact skeletons were found in shallow trenches dug into the solid clay subsoil and one intact stone sarcophagus was discovered at the end of the tunnel opened to the west (fig. 1). The contents of this sarcophagus had not been disturbed, even though a nineteenth-century clay pipe was found only a few centimeters to one side. The body, which had completely disintegrated, was wrapped in a simple, coarsely woven, woolen shroud without any objects of any type that might assist in its identification. The character of the sarcophagus and of the burial make it possible that it was a Carolingian interment. A small metal disk was found in another tomb, but expert examination did not reveal any markings that could lead to its identification.

[17] Hubert, J., *L'Art Pré-roman*, 20, Paris, 1938.

[18] Panofsky, E., *Abbot Suger*, 208–212.

[19] ". . . jedoch ohne Westtürme," *Kunst-Chronik*, 11, vom Zentralinstitut für Kunstgeschichte in München, Nürnberg, October, 1948.

then associated with work done during Charlemagne's reign. I offer this as a possible solution for this problem until further evidence is available.

ATRIUM

One final question remains to be discussed in relation to the Carolingian narthex. The manuscript discovered by Dr. Morper evidently mentions a western atrium.[20] In my first volume I included such an atrium in the reconstruction of Fulrad's church. It has been subsequently pointed out that by the eighth century the word *atrium* did not necessarily mean an enclosed court to the west of a church, as in Early Christian times, but that it referred generally to a cemetery.[21] It is true that no masonry has been discovered during the excavations to indicate a western court. Indeed both to the north and to the south the Carolingian *libages* foundations stop at the west wall of the Carolingian narthex. Numerous burials do exist west of the Carolingian church and, as mentioned before, a Merovingian cemetery existed just north of the building. It seems certain, therefore, that the area west of the Carolingian narthex was considered hallowed, at least as a burial ground, but we have no evidence for any architectural enclosure.

SUMMARY OF NARTHEX PLAN

If it is impossible, at this time, to give a complete reconstruction of the western ensemble of Fulrad's church, we can at least be reasonably specific about a number of its features. In summary the following conclusions may be drawn: the Carolingian church was originally planned with a narthex at the west end of the nave. The plans of this narthex were evidently changed when Pepin the Short decided to include in it a western polygonal apse on the central axis of the building possibly as a burial chamber, or royal chapel. At Pepin's death, or presumably somewhat earlier, he adopted a much more humble attitude and ordered that he be buried outside at the threshold of the main entrance, which was a narrow hall, to the north of the apse.[22] To the south of the apse a similar narrow hall served as an entrance for the monks, who were possibly shielded from public view by a walled passage or corridor leading from the claustral buildings to this door. In honor of his father, Pepin, Charlemagne added to the narthex, possibly by building two small towers at the north and south extremities of the narthex. The exact shape, as well as the location of these towers, however, still remains hypothetical.

Although it is always tempting to propose complete reconstructions of archeological discoveries, it would seem more prudent at present to proceed no further than the plan, which is shown in figure 9. I should, nevertheless, like to discuss a few comparable western ensembles before bringing this article to its close in order to lend, perhaps, additional weight to the proposed plan and to explain its function more clearly.

COMPARABLE EARLY WESTERN APSES

The most striking and unexpected feature in this reconstruction is quite obviously the western polygonal apse, as well as the early date at which it was built. Churches with apses at both ends of the building are familiar to all students of German Romanesque architecture of the tenth to the thirteenth centuries and it has been recognized that this form appeared frequently in the ninth-century churches of northern France.[23] Only a few, however, can be given a date as early as 768, the date of Pepin the Short's death, when it seems certain that the western apse at St.-Denis was already under construction.

It is likewise true that until very recently the original function or significance of such apses was a matter of conjecture. Historians of art have recognized their early presence in the Christian architecture of western Europe, although usually as isolated, or rather unique, examples.[24] Their more frequent occurrences as early as the fifth century in North Africa, with a number of specific inscriptions, has led generally to the the-

[20] "Atrium im Westen . . . ," *Kunst-Chronik, loc. cit.*

[21] Panofsky, E., *Abbot Suger,* 157–158. See also Hubert, J., *L'Art Pré-Roman,* 65–66.

[22] An empty tomb was discovered in just this location. Its simple construction of uneven stones placed against the masonry of the agglomerate, mat foundations, which were removed to make place for the sarcophagus, seems surprising, however, for a royal burial, no matter how humble.

[23] Hubert, J., *L'Art Pré-Roman,* 65–69.

[24] Among the more frequently mentioned examples are: in Italy, Valpolicella (dated eighth century; R. de Lasteyrie *L'Architecture Religieuse en France à l'Epoque Romane,* 34, Paris, 1929); in Spain, Sant Pere del Burgal (". . . this double-ended plan is unique in Catalonia," W. M. Whitehill, *Spanish Romanesque Architecture of the Eleventh Century,* 16, Oxford, 1941); in England, Abingdon (dated *ca.* 680 by A. W. Clapham, *English Romanesque Architecture before the Conquest,* 36, Oxford, 1930); in France, the earliest ones are in the ninth century, i.e. St. Sauveur de Fulda, 819, and the projected plan for St. Gall, 819 (C. Enlart, *Manuel d'Archéologie Française, Architecture Religieuse* I: 181, Paris, 1920).

ory that these western apses served as burial places for particularly favored ecclesiastics.[25] This theory has been upheld by Professor Grabar in his meticulous study of *martyria* and the cult of relics.[26]

There are two other observations in Professor Grabar's book that are of especial interest in solving the riddle of the western apse at St.-Denis. In discussing the form of round or polygonal funerary monuments, he notes that the Christian use of such structures was apparently restricted to "imperial" sepultures.[27] This is particularly interesting when it is also observed that the polygonal form is maintained in Christian "imperial" architecture of the eighth century.[28] Fulrad, who in addition to being Abbot of St.-Denis was royal Arch-chaplain for both Pepin the Short and Charlemagne, may very well have had this significant meaning of polygonal forms in mind when he planned the eastern apse of St.-Denis in this manner. And it would seem only natural for such a form to have been chosen for Pepin's western apse.

REASON FOR WESTERN APSE AT ST.-DENIS

The other interesting fact is that one of the possible origins, or reasons, for western apses can be found in the fact that the "imperial loges" or royal chapels were situated on the central axis of a church, facing the high altar.[29] This custom provides another possible explanation for the presence of the western apse at St.-Denis. One might suppose that Pepin the Short instructed Abbot Fulrad to include this apse in the narthex with the intention of being buried there; and that, after Pepin chose another burial place, the apse was retained as a royal loge, in recognition of the particular esteem in which Saint Denis was held by French kings as the protector and patron of the monarchy.[30] Two other factors seem to support this hypothesis. If the western apse had functioned as a *martyrium* or chapel dedicated to a particular Saint, mention of this dedication or of an altar in the chapel would certainly have appeared in the texts which describe the other altars in the Carolingian church. No such mention is made. Furthermore the marked discrepancy between the dimensions of the eastern and western apses would indicate a secondary, possibly secular, function for the smaller one to the west.

The inclusion, or addition, of two towers, whatever their exact form or location, in the ensemble of the narthex construction at St.-Denis, gives this western structure added significance. It has been established that two-tower façades existed in western Europe possibly as early as the sixth century, even though the full exploitation of this monumental concept did not occur until the eleventh century.[31] The presence of such towers at St.-Denis must have formed an important influence in the evolution of the façade and it is certainly to be hoped that enough evidence will ultimately be available to reconstruct them with assurance.

The plan of the Carolingian narthex at St.-Denis as presented in this article makes it possible to complete the plan of Fulrad's entire church with considerable accuracy. There is no need to review the whole reconstruction at this time. It is sufficient to recall that Fulrad's church may be regarded as the first Carolingian church and that the plan now available confirms the importance of St.-Denis, the royal abbey, in the development of medieval architectural forms.

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[25] The most familiar basilica with a western apse is Orleansville in Algeria, where a text identifies the construction with the tomb of Bishop Reparatus, who died *ca.* 475, Gsell, S., *Les Monuments Antiques de l'Algérie,* II: 240, Paris, 1901. There are a number also in Tunisia; basilicas of Henchir Chigarnia, of Feriana, of Mididi, all dated in the fifth or sixth centuries, see Gauckler, P., *Basiliques Chrétiennes de Tunisie,* 8–9, 20, and plates XXIV, XXVIII, Paris, 1913.

[26] "Ce sont à coup sûr les contre-absides d'Afrique-et peut-être celles de la Gaule mérovingienne-qui nous permettent de saisir la fonction initiale de toutes les constructions de ce type rattachées au mur occidental des basiliques. Les contre-absides africaines étaient des monuments funéraires, et c'est à ce titre, et en vertu d'un processus général souvent observé, que certain martyria en avaient adopté la formule. Autrement dit si les *augmenta* en forme d'abside adoptent un type architectural qui sert par ailleurs à plus d'un *martyrium,* ils doivent cette parenté à leur source commune qui est l'exèdre funéraire." Grabar, A., *Martyrium, recherches sur le culte des reliques et l'art chrétien antique* I: 540–541, Paris, Collège de France, 1946.

[27] Grabar, A., *op. cit.,* 143.

[28] St. Sophia, Benevento, Italy, before 768, royal chapel of Arechis, King of the Lombards; the palace chapel of Nimeque, Holland, consecrated in 799; and Charlemagne's own palace chapel at Aachen, built between 796–814. Hubert, J., *L'Art pré-Roman,* 75.

[29] Aix-la-Chapelle, 796–814; Seligenstadt, 830, and Palermo, twelfth century. Grabar, A., *Martyrium* I: 541, Paris, 1946.

[30] See my first volume, *Abbey of St.-Denis, 475–1122,* 48–52.

[31] Schaefer, H., The origin of the two-tower façade in romanesque architecture, *Art Bull.* **27**: 102–104, 1945. Another example of a ninth-century two-tower façade has recently been published—the abbey church of Faremoûtiers, Lantier, R., and J. Hubert, *L'Art Français des Origines à l'Epoque Romane,* fig. 65, Paris, 1947.

RECENT EXPLORATION OF THE INFRA-RED SOLAR SPECTRUM AT THE MCMATH-HULBERT OBSERVATORY

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ABSTRACT

An account is given of the solar infra-red research program, which is being carried out jointly by the authors and by Doctors O. C. Mohler and A. K. Pierce at the McMath-Hulbert Observatory.

The infra-red solar spectrum has been recorded with high resolution from 1.4 μ to 3.6 μ with the aid of new instrumentation consisting of the McGregor spectrometer, two Cashman PbS cells and a Wilson amplifier. Broad areas of the solar spectrum are completely masked by absorption in the earth's atmosphere, but three relatively transparent "windows," centered approximately at 1.6 μ, 2.2 μ and 3.3 μ, permit recording of many hundreds of previously unobserved absorption lines.

The new lines originate both from atoms in the sun's outer envelope and from molecules in the atmosphere of the earth. Among the prominent telluric features of the spectrum are eight bands of ordinary carbon dioxide, as well as five that arise from the isotopic forms $C^{13}O_2^{16}$ and $C^{12}O^{16}O^{18}$. In addition, the spectrum reveals five bands of methane and three of nitrous oxide. Approximately four hundred new solar lines appear on the tracings, the most intense lines being due to neutral atoms of H, Mg, Si, and Fe, and the majority of them having excitation potentials in excess of five volts. A section of the infra-red spectrum of a small sunspot has also been recorded.

Observations of solar limb darkening have been carried to an infra-red limit of 18 μ, with the aid of a Perkin-Elmer spectrometer attached to the Francis C. McMath 24-inch reflector.

The significance of the new infra-red data in improving our knowledge of the atmospheres of the sun and earth is discussed.

CONTENTS

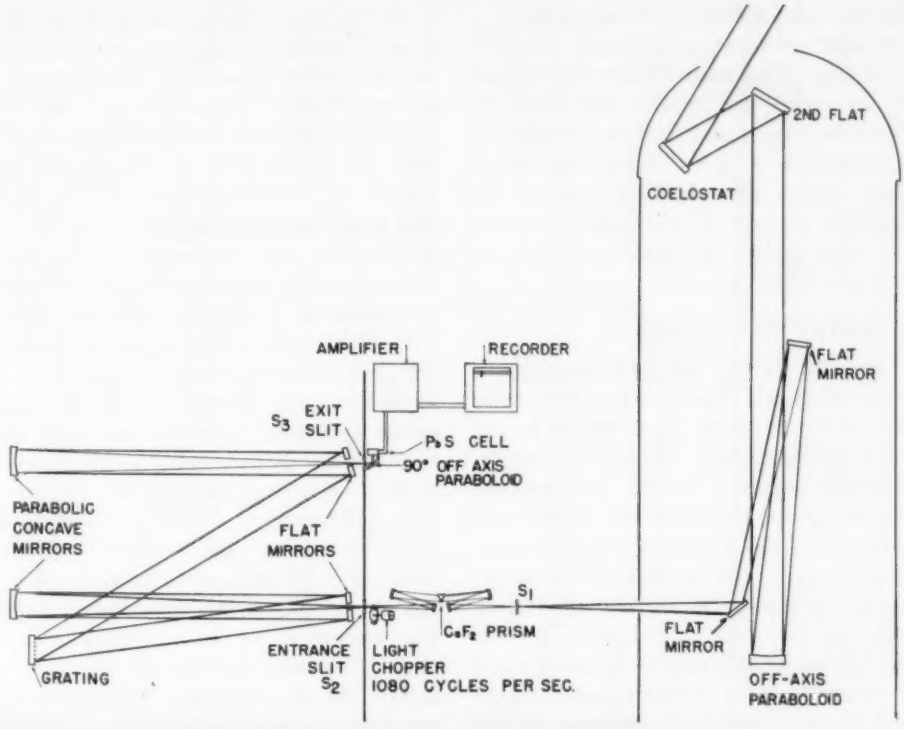
	PAGE
Introduction	362
Instrumentation	364
High-Lights of the Infra-red Solar Spectrum	364
Region 1.5 μ–1.78 μ	364
Region 1.95 μ–2.45 μ	367
Region 2.9 μ–3.6 μ	369
Research Problems of the Infra-red Solar Spectrum	369
Wave Length Measurements and Identification of Solar Lines	369
Solar Limb Darkening	370
Interpretation of Solar Line Intensities	370
Sunspot Spectra	372
Problems of the Earth's Atmosphere	372

INTRODUCTION

EARLY in 1947 the McMath-Hulbert Observatory entered on a long-range program of exploration and study of the infra-red solar spectrum in the region between 1.4 μ and 3.6 μ. This spectral region has always been an elusive one. Shorter wave lengths can be reached with high resolution by the photographic plate, whereas it is well known that very high resolution, in frequency units, is attainable with the thermocouple or bolometer in the far infra-red. The gap at intermediate wave lengths may now be filled, thanks to the development of the lead-sulfide photo-conductive cell by Dr. Robert J. Cashman. The PbS cell has remarkable sensitivity in the range 1 μ to 3 μ when it is used at room temperature, and extension of the infra-red limit of sensitivity to beyond 3.5 μ may be achieved with refrigeration. Through the kindness of Dr. Cashman, the McMath-Hulbert Observatory was able to secure a PbS cell in the spring of 1947 and it has been in use ever since, initially in conjunction with a Littrow-type spectrograph in the McGregor Tower and later with an all-reflecting spectrometer of the Pfund type. The original Cashman cell is uncooled and permits recording of the solar spectrum to about 2.5 μ with a maximum resolving power of about 50,000 at 1.6 μ. More recently Dr. Cashman has supplied us with a quartz-encased PbS cell which may be refrigerated to − 80° C. and with which the solar spectrum has been recorded to 3.6 μ.

We shall not attempt to give a complete account here of the many important earlier investigations of the infra-red solar spectrum, notably by Langley, Abbot, Adel, and Migeotte. The early explorations by Langley and Abbot,[1] which were of adequate resolution to show the most prominent features of the spectrum, were made with a bolometer and a rock salt prism and extended to about 5.3 μ. The map by Langley and Abbot, which is shown in figure 2, upper left, serves as a convenient guide to the present investigation. The region of the spectrum below 1.4 μ is accessible to the photographic plate and has been recorded with high precision by many observers. The re-

[1] Langley, S. P., and C. G. Abbot, The absorption lines in the infra-red spectrum of the sun, *Ann. Astrophys. Obs. Smithsonian Inst.* **1**: 127, 1900.



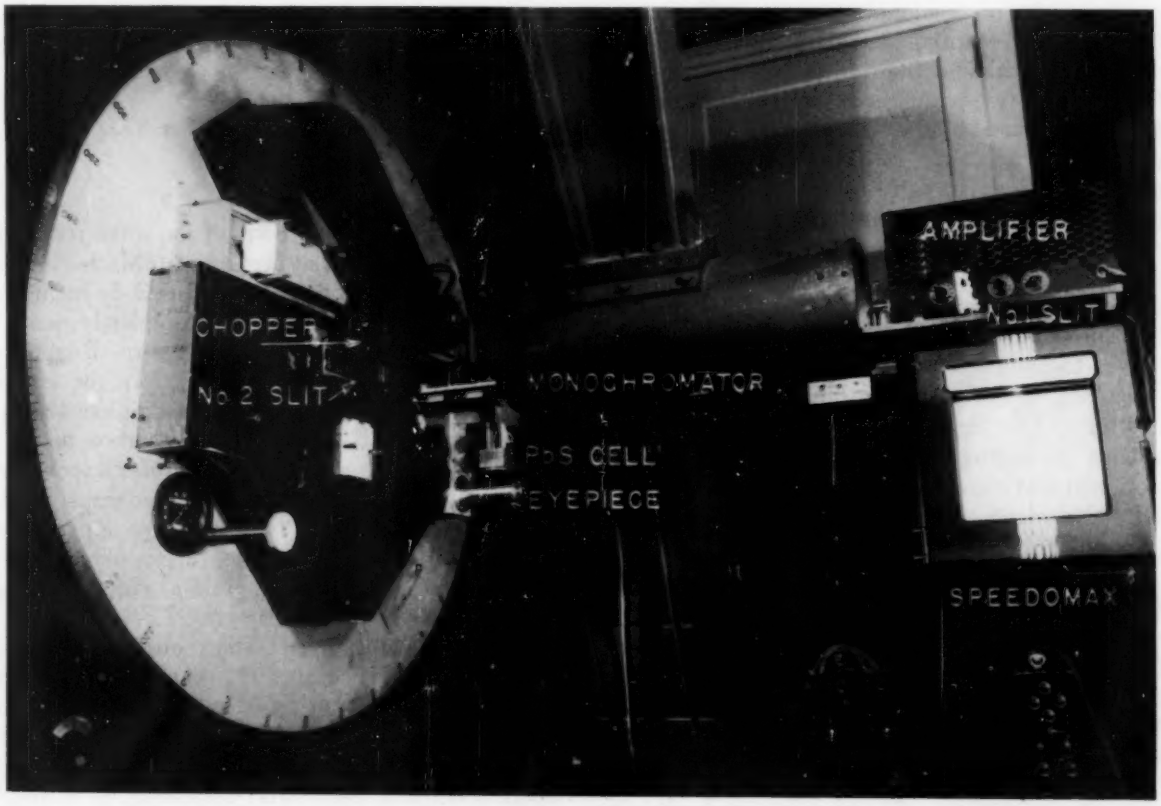


FIG. 1. *Upper:* Schematic drawing, McGregor tower telescope and spectrometer. *Lower:* Observing room, McGregor spectrometer.

gion to which the lead-sulfide cell responds, and with which we are primarily concerned, extends from 1.0 μ to 3.6 μ. The map shows that broad areas of the spectrum are totally absorbed by molecules of water vapor and carbon dioxide in the earth's atmosphere at 1.4 μ, 1.8 μ, and 2.6 μ. The intervening spaces are relatively clear of absorption, however, and it is to these so-called "windows" of the earth's atmosphere that we shall direct our attention.

INSTRUMENTATION

A detailed account of the infra-red equipment at the McMath-Hulbert Observatory has been given elsewhere,[2] but a brief description is included here for completeness. Figure 1, upper, shows a schematic drawing of the seventy-foot McGregor Tower and of the infra-red spectrometer. After reflection from a pair of plane mirrors at the top of the tower, the sunlight is reflected from an off-axis paraboloidal mirror of twelve inches diameter and fifty-foot focal length. Aided by further reflections from a pair of auxiliary flat mirrors, the off-axis mirror forms a solar image about five and one-half inches in diameter at the entrance slit of a monochromator. The monochromator is essentially a small spectroscope consisting of a calcium fluoride prism together with two flat and two paraboloidal mirrors. The short spectrum formed by the monochromator is focused on the entrance slit of the spectrometer, after passing through a rotating shutter, or "light chopper," which interrupts the light beam at the rate of 1,080 cycles per second. Rotation of one of the paraboloidal mirrors of the monochromator causes any desired region of the spectrum to enter the spectrometer slit. The monochromator thus serves to eliminate contamination of the infra-red spectrum by overlapping higher orders of the grating. The light chopper makes possible the use of a narrow-band AC amplifier especially designed and constructed by Mr. Wallace Wilson, Dr. Cashman's associate at the Northwestern Technological Institute.

The all-reflecting spectrometer is of the Pfund type with an equivalent focal length of twenty-three and one-half feet. The spectrum is formed by a plane reflection grating ruled fifteen thousand lines per inch and generously loaned by the Mount Wilson Observatory through the courtesy of Dr. I. S. Bowen. The grating is unusual in that it gives a relatively high concentration of energy in the first order near 2 μ. Professor E. F. Barker, of the Physics Department of the University of Michigan, has also kindly supplied a five thousand line per inch grating for observations beyond 2.5 μ. A combination of four mirrors, two flat and two paraboloidal, perform the functions of collimating and focusing. The monochromatic radiation that passes through the exit slit of the spectrometer strikes an off-axis paraboloidal mirror, which turns the beam of radiation through 90° and simultaneously focuses it on the sensitive surface of the detector. In this way the width of the spectrum is compressed from about 16 mm. to less than ½ mm., with a resulting high concentration of energy on the tiny sensitive cell area. The cell current, which is variable according to the intensity of the incident radiation, is then magnified by the amplifier and used to actuate a Leeds and Northrup Speedomax recorder. During operation of the spectrometer the grating slowly rotates, usually at the rate of 0°.5 per hour. As the spectrum drifts across the cell, the recorder automatically traces out the intensity at each point along the spectrum. Figure 1, lower, shows a view of the observing end of the spectrometer.

HIGH-LIGHTS OF THE INFRA-RED SOLAR SPECTRUM

REGION 1.5 μ–1.78 μ

Reproductions of sections of the infra-red solar spectrum as observed at the McMath-Hulbert Observatory are shown in figures 2–5, inclusive. At 1.4 μ the solar spectrum is completely masked by the great Ψ band of water vapor. Beginning at about 1.5 μ and extending to 1.78 μ the atmosphere is transparent except for incomplete absorption by molecular band systems of carbon dioxide, methane, and water vapor. The water vapor lines become increasingly strong and numerous as the two boundaries of the "window" are approached. Four bands of carbon dioxide are conspicuous at 1.54 μ, 1.57 μ, 1.60 μ and 1.65 μ (fig. 2, upper right). The two weak bands at 1.54 μ and 1.65 μ appear fully developed when observed at low solar altitudes. The CO_2 bands are of the vibration-rotation type, as are all molecular bands that occur in this region of the spectrum. They were first recorded by Langley and Abbot in the solar spectrum, each band appearing as a single small notch (see fig. 2, upper left), and were

[2] McMath, R. R., and O. C. Mohler, A solar infra-red reflecting spectrometer, *Sky and Telescope* 7 (6): 143, 1948; *Jour. Op. Soc. Amer.*, in press.

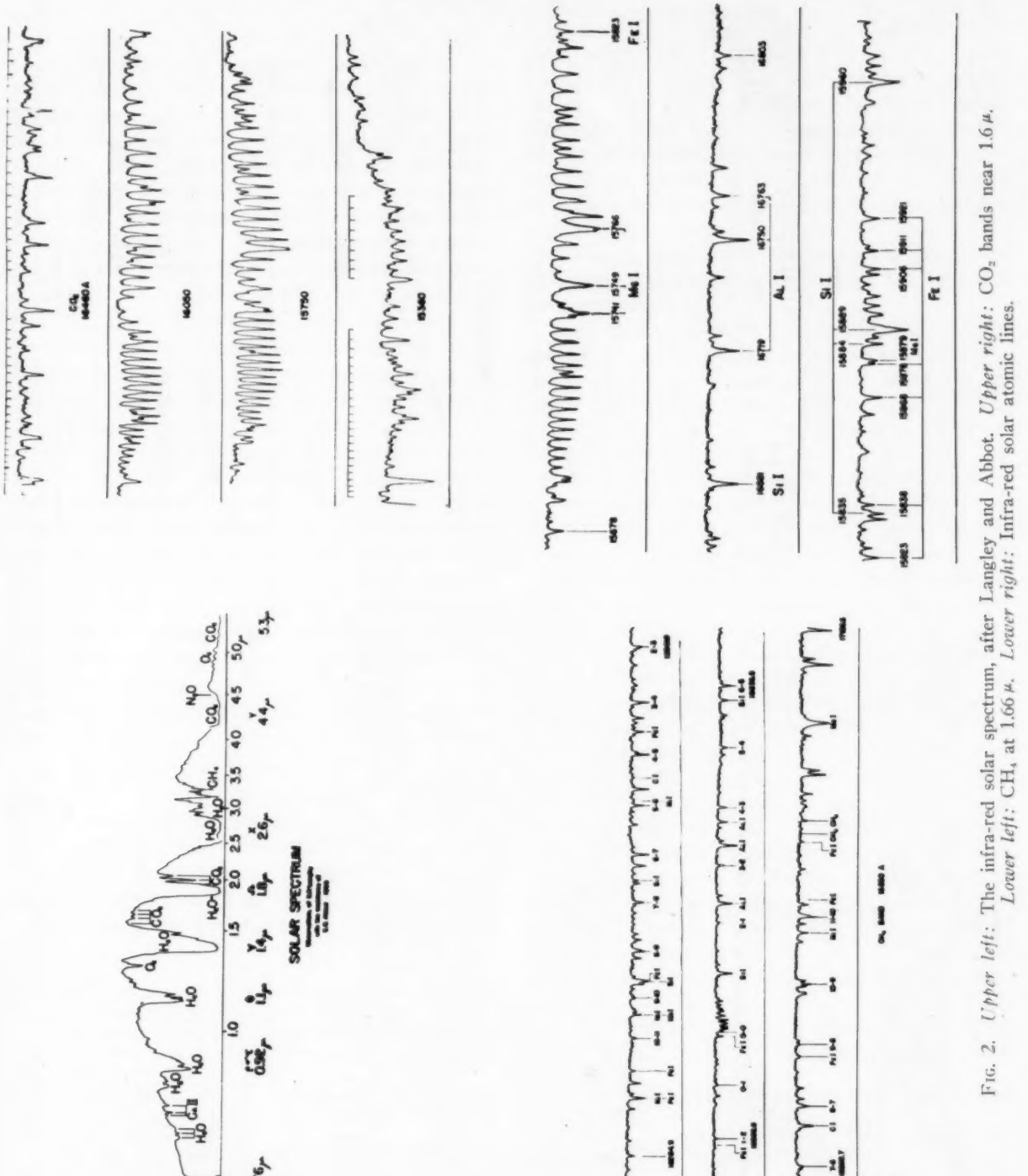


FIG. 2. *Upper left:* The infra-red solar spectrum, after Langley and Abbot. *Upper right:* CO_2 bands near 1.6 μ.
Lower left: CH_4 at 1.66 μ. *Lower right:* Infra-red solar atomic lines.

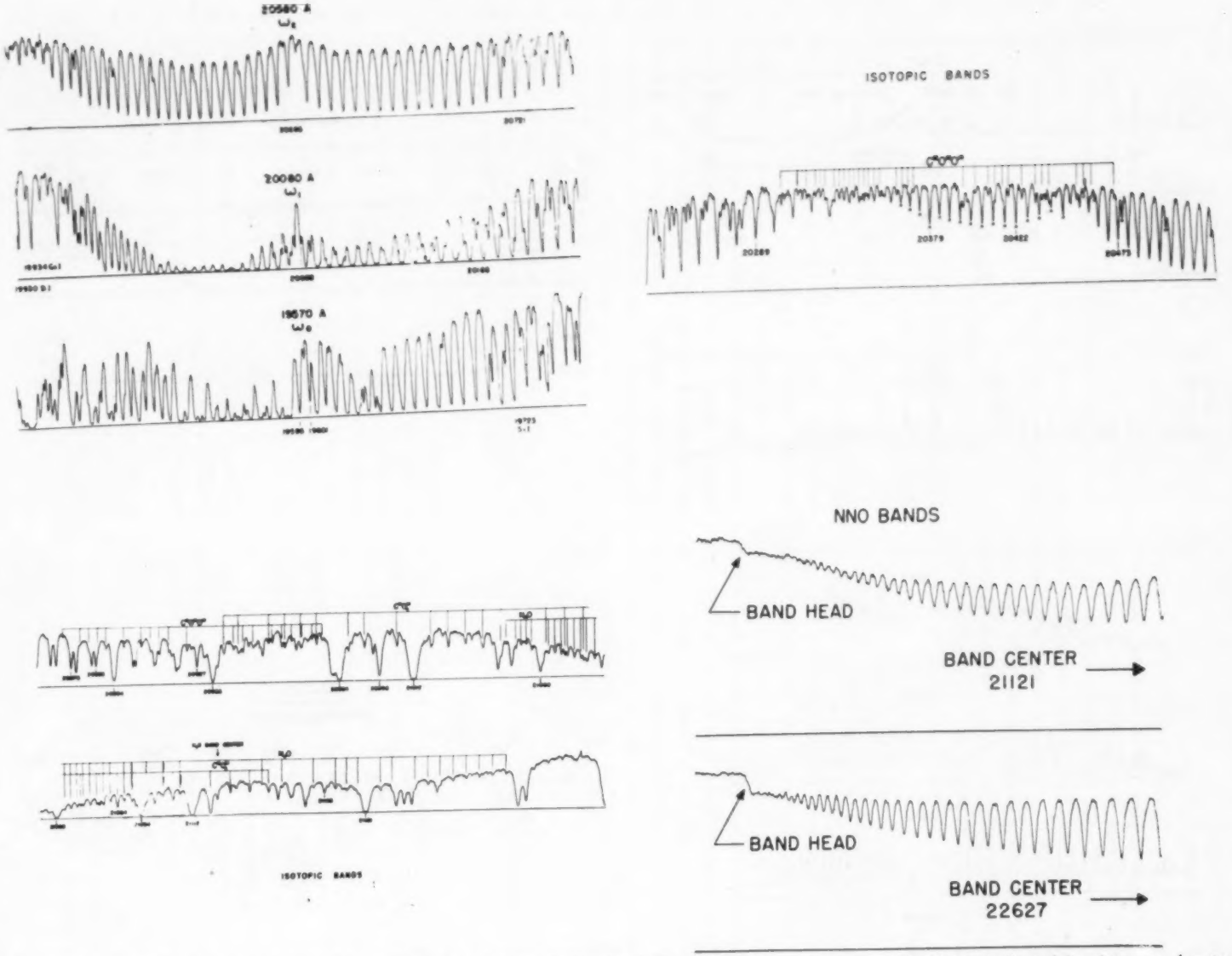


FIG. 3. *Upper left:* CO_2 bands near 2 μ. *Upper right:* Isotopic bands of CO_2 in the solar spectrum. The lines indicated by dots are due to $C^{13}O_2^{16}$. *Lower left:* The N_2O band at 2.13 μ and isotopic bands of CO_2. *Lower right:* Laboratory spectra of N_2O.

later observed in the laboratory by Barker and Wu.[3] The identification of the solar bands as due to CO_2 was made by Adel and Lampland.[4]

In addition to bands like those of carbon dioxide, which had been recognized previously in the solar spectrum, although unresolved, a number of new band systems have been found on the tracings. The first infra-red observations at Lake Angelus in the summer of 1947 revealed an interesting band structure at 1.66 μ, which was later identified [5] as an overtone band of methane in the earth's atmosphere. This identification constituted an independent confirmation of the discovery of atmospheric methane by Migeotte [6] from observations of the fundamental band at 3.3 μ. As shown by figure 2, lower left, the methane band consists of two widely-spaced series of lines (positive and negative branches) on either side of a closely-spaced group of lines (zero branch).

The 1.6 μ region of the solar spectrum is also rich in lines that are produced by absorption in the atmosphere of the sun. Such lines may be distinguished from telluric lines by comparison of tracings made with the noon-day sun with those obtained at low solar altitudes. Approximately four hundred new solar lines have been found on the infra-red tracings,[7] the vast majority of them not previously observed in the laboratory. As expected, most of these lines have excitation potentials in excess of five volts. A number of the new lines are shown in figure 2, the most prominent ones being due to neutral atoms of magnesium, iron, silicon, and aluminum. Especially conspicuous are the unusually wide magnesium lines, which are known to be particularly susceptible to pressure broadening. The seventh member of the Brackett series of hydrogen appears as a wide shallow depression in the continuous spectrum at λ 16,800.

[3] Barker, E. F., and Ta-You Wu, Harmonic and combination bands in CO_2, *Phys. Rev.* **45**: 1, 1934.

[4] Adel, Arthur, and C. O. Lampland, A new band in the absorption spectrum in the earth's atmosphere, *Astrophys. Jour.* **87**: 198, 1938.

[5] McMath, R. R., O. C. Mohler, and L. Goldberg, Telluric bands of methane in the Fraunhofer spectrum, *Phys. Rev.* **73**: 1203, 1948.

[6] Migeotte, M., Spectroscopic evidence of methane in the earth's atmosphere, *Phys. Rev.* **73**: 519, 1948; Methane in the earth's atmosphere, *Astrophys. Jour.* **107**: 400, 1948.

[7] Goldberg, L., O. C. Mohler, and R. R. McMath, New solar lines in the spectral region 1.52 μ–1.75 μ, *Astrophys. Jour.* **109**: 28, 1949.

REGION 1.95 μ–2.45 μ

Beyond 1.78 μ the solar spectrum is again totally absorbed by water vapor, this time by the Ω band, which extends to about 1.95 μ. The region 1.95 μ–2.45 μ is more or less completely transparent. The map by Langley and Abbot shows three prominent features at the long wave length end of the Ω band which are due to carbon dioxide. These bands, at 1.95 μ, 2.01 μ, and 2.05 μ, were first resolved by Adel,[8] but their structures appear in considerably finer detail on the new records (fig. 3, upper left). Note also the solar lines of neutral calcium and silicon that fall between the strong lines of CO_2.

The carbon dioxide bands, which, strictly speaking, have their origin in molecules of $C^{12}O_2^{16}$, are so intense as to suggest the presence also of bands due to the isotopes $C^{13}O_2^{16}$ and $C^{12}O^{16}O^{18}$. Laboratory studies indicate abundance ratios of 1.1 per cent for $C^{13}:C^{12}$ and 0.2 per cent for $O^{18}:O^{16}$. The existence in the earth's atmosphere of the isotopic molecules $O^{16}O^{18}$ and $O^{16}O^{17}$ has already been established by the discovery of the corresponding bands in the solar spectrum.[9] As companions to each of the three strong bands of $C^{12}O_2^{16}$ there should appear two very much weaker bands corresponding to $C^{13}O_2^{16}$ and $C^{12}O^{16}O^{18}$. Theory predicts that the companion bands will be shifted to longer wave lengths by various amounts ranging from 58 cm^{-1} to 115 cm^{-1}.

Examination of the tracings reveals five of the six expected bands very close to the calculated positions;[10] the remaining one happens to coincide with, and is masked by, one of the strong bands of ordinary CO_2. Three of the isotopic bands are shown in figure 3, upper right and lower left. The regularity of the line spacings is quite apparent even though many individual lines are masked by coincident and neighboring lines of water vapor and carbon dioxide. On theoretical grounds, it is to be expected that the bands corresponding to the heavy carbon variety of CO_2 will have precisely the same form and spacing as those of ordinary CO_2. On the other hand, the

[8] Adel, Arthur, Resolution of the telluric bands ω_1 and ω_2, *Astrophys. Jour.* **97**: 190, 1943.

[9] Dieke, G. H., and H. D. Babcock, The structure of the atmospheric bands of oxygen, *Proc. Nat. Acad. Sci.* **13**: 670, 1927; Babcock, H. D., Some new features of the atmospheric oxygen bands of the relative abundance of the isotopes O^{16}, O^{18}, *ibid.* **15**: 47, 1929.

[10] Goldberg, L., O. C. Mohler, and R. R. McMath, Isotopes of carbon and oxygen in the earth's atmosphere, *Phys. Rev.* **74**: 1881, 1948.

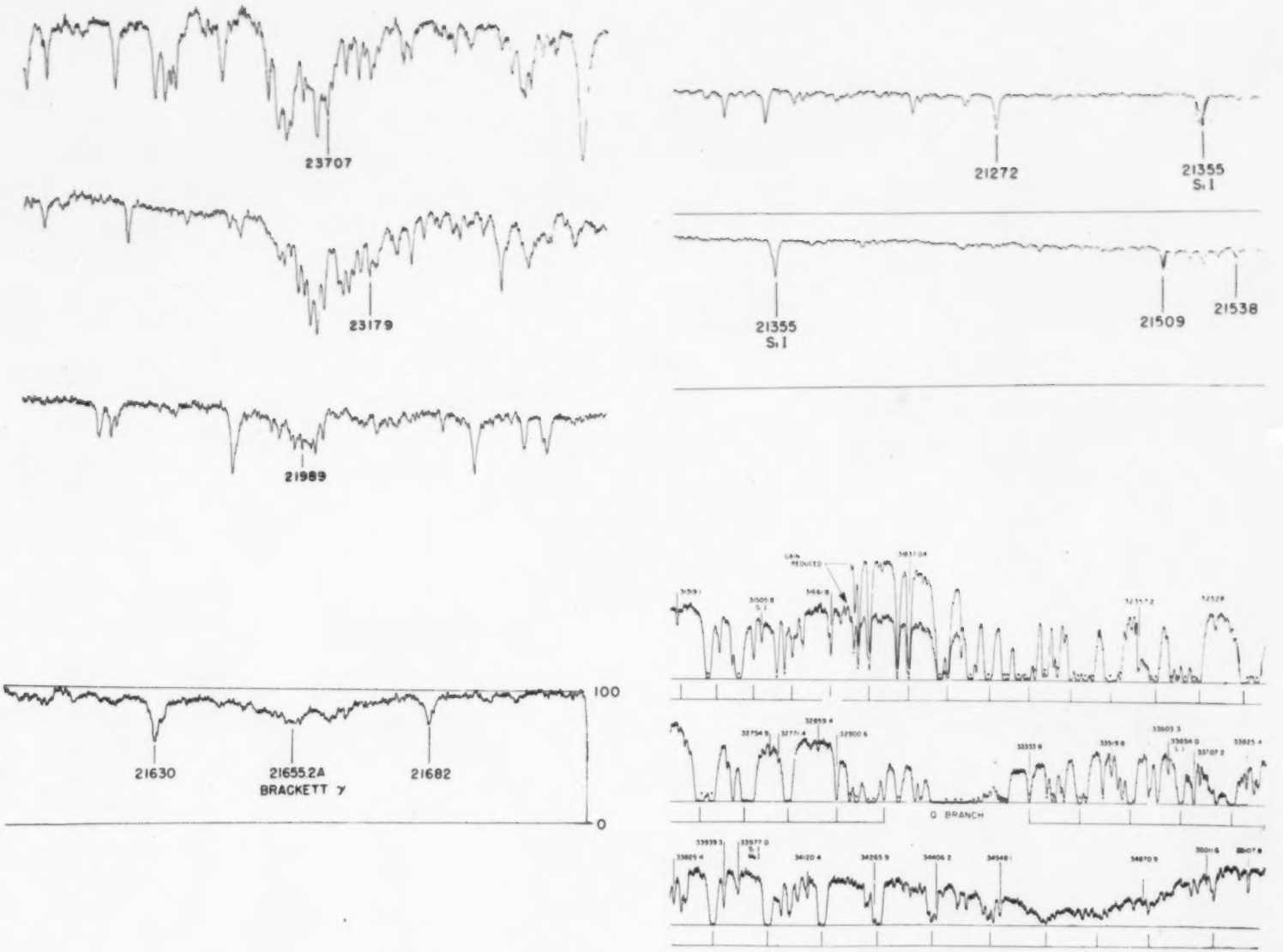


FIG. 4. *Upper left:* CH_4 bands. *Upper right:* Si I at λ21355. *Lower left:* Third member of the Brackett series of hydrogen. *Lower right:* The 3.3 μ region of the solar spectrum. Lines of water vapor are indicated by dots, those of CH_4 by vertical lines.

bands of the heavy oxygen isotope are expected to exhibit one half of the ordinary line spacing. The observed band patterns agree precisely with those predicted.

The 2 μ region of the solar spectrum also reveals other new bands. Two of these, located at 2.13 μ and 2.26 μ, are due to nitrous oxide, N_2O. Portions of the bands, as observed in the laboratory, appear in figure 3, lower right. As a by-product of the solar studies, laboratory spectra of this type have been analyzed to yield improved values for the moments of inertia and for some of the potential constants of carbon dioxide, methane, and nitrous oxide. The spectroscopic evidence for the presence of nitrous oxide, or laughing gas, in our atmosphere was first given by Adel about ten years ago, and confirming observations have recently been made by Migeotte at Ohio State and by Sutherland and his co-workers in England. Still another new band, unusual in that its lines occur in pairs or doublets, overlaps the band of one of the oxygen isotopes at 2.08 μ. On the basis of the location, appearance, and intensity of this band it has been identified as arising from an excited state in the CO_2 molecule.[11] Of further interest in this general region of the spectrum are three prominent absorption features due to CH_4, at 2.20 μ, 2.32 μ, and 2.37 μ (fig. 4, upper left).

Although the solar spectrum in the neighborhood of 2.2 μ abounds in interesting molecular bands of telluric origin, it is noticeably deficient in solar lines, in marked contrast to the relatively rich spectrum at 1.6 μ. The scarcity of solar lines in this region is illustrated in figure 4, upper right. Only one solar line, due to neutral silicon, is found in a spectrum interval of 237A. The significance of this point will be discussed later in this paper. The solar lines that are present, however, are unusual for their high excitation and are therefore extremely important in terms of the structure of the solar atmosphere. A good example is the third member of the Brackett series of hydrogen (fig. 4, lower left) which has the broad shallow appearance characteristic of hydrogen atoms disturbed by pressure effects.

REGION 2.9 μ–3.6 μ

Due to absorption by the X band of water vapor and carbon dioxide in the earth's atmosphere, the effective limit of sensitivity of the uncooled Cashman cell is at 2.5 μ. The third infra-red atmospheric window begins at about 2.9 μ and extends beyond 4.0 μ. With the refrigerated PbS cell the study of the solar spectrum has been extended with improved resolution to 3.6 μ (fig. 4, lower right). The most prominent feature of this region of the spectrum, apart from many lines of water vapor, is a strong band of methane centered at about 3.3 μ. In figure 4 the lines of water vapor are indicated by black dots and those of methane by vertical lines. The methane band was first resolved in the solar spectrum by Adel[12] in 1940. Migeotte[13] observed the same band in 1948 and identified it as due to methane. The new tracing shows considerably improved resolution. The centers of the lines appear completely black, which is not shown by the earlier tracings, and the higher series members show the multiplicity characteristic of CH_4. Solar lines of neutral magnesium and silicon also appear on the new tracings, as well as a band of N_2O at 2.97 μ.

RESEARCH PROBLEMS OF THE INFRA-RED SOLAR SPECTRUM

WAVE LENGTH MEASUREMENTS AND IDENTIFICATION OF SOLAR LINES

We turn now to a brief discussion of research problems connected with the infra-red solar spectrum. The first problem that is encountered in entering a new region of the spectrum is the basic one of mapping, that is to say, the measurement of wave lengths and the identification of lines in terms of known atoms and molecules. The first phase of this problem, namely, the determination of wave lengths, has been solved in a very satisfactory way through use of the higher order spectra formed by the spectrometer grating. The wave lengths of infra-red lines may be expressed as integral multiples of known solar wave lengths in the visible spectrum. In this way the infra-red wave lengths have been determined with a precision of about 0.1 A, which is entirely adequate to establish identifications.

The definitive identification of new lines in the solar spectrum rests upon comparisons with spectra of known atoms and molecules observed in the laboratory. The observation in the laboratory of infra-red atomic spectra beyond 1.4 μ has hardly

[11] Mohler, O. C., R. R. McMath, and L. Goldberg, Excited state bands of atmospheric CO_2, *Phys. Rev.* **75**: 520, 1949.

[12] Adel, Arthur, Comparison of atmospheric methane content above Flagstaff, Arizona, and Columbus, Ohio. *Phys. Rev.* **75**: 322, 1949.

[13] *Op. cit.*

begun, however, and published data are at present available only for a small number of lines observed with the bolometer or thermocouple. It is understood that programs for the systematic study of infra-red atomic spectra with the PbS cell are now under way at a number of laboratories. In the absence of laboratory data the identification of solar lines rests on the prediction of wave lengths by computation of differences between known atomic energy levels.[14] To date about one-third of the solar infra-red lines have been thus identified, approximately 100 of them between 1.52 μ and 1.75 μ, and 50 between 1.95 μ and 3.6 μ. The following atoms, all of them neutral, are represented in the infra-red spectrum: H, C, Na, Si, Mg, Al, Ca, Fe, Mn, and Ni. The identification of molecular lines of the earth's atmosphere is in a somewhat more satisfactory state, because it is a simple matter to secure laboratory molecular spectra of high resolution with the solar spectrometer. A high-intensity direct current carbon arc is used as a light source, with an absorption cell containing a gas sample placed between the source and the entrance slit. In figure 5, upper left, we compare, for example, a section of the solar spectrum at 1.66 μ with the laboratory spectrum of methane in the same wave length region.

SOLAR LIMB DARKENING

One of the most fundamental problems in solar physics is the construction of a theoretical solar atmosphere that will function in accordance with known physical laws to reproduce the observed features of the Fraunhofer spectrum. The sun's continuous radiation is compounded of contributions from many regions at all depths in the solar atmosphere down to the level where the solar gases become opaque. Once the mechanism that produces the opacity is known it becomes possible, from observations of solar limb darkening, to construct models of the solar atmosphere in which the increase of both pressure and temperature with depth is taken into account. Such model atmospheres have been derived by Stromgren[15] and later by Münch,[16] following the identification of the negative hydrogen ion as the source of opacity.[17]

The parameters of the model atmospheres are based almost entirely on measurements of solar limb darkening by Abbot.[18] Because of instrumental limitations, Abbot's observations did not extend beyond about 2.4 μ and also did not reach beyond 95 per cent of the solar radius. Measures similar to those of Abbot's are now being made at the McMath-Hulbert Observatory to an infra-red limit of about 20 μ. The new observations, which are nearly completed, also approach more closely to the solar limb. The observations beyond 3.6 μ have been carried out with a 24-inch Cassegrain reflector to which is attached a Perkin-Elmer spectrometer, purchased with a grant from the Research Corporation. Sample observations of solar limb darkening are shown in figure 5, upper right. The decrease of limb darkening with increasing wave length is conspicuous. The solid curves are drawn from the new observations, whereas the solid dots represent Abbot's observations at 20,970 A. The open circles are also interpolated from Abbot's observations at two wave lengths adjacent to 8,000 A and show excellent agreement with the new results.

INTERPRETATION OF SOLAR LINE INTENSITIES

The intensity of a spectrum line depends upon the density, pressure, and temperature of the gas in which the line originates. In the sun, these quantities vary with depth within the atmosphere. The depth at which a solar spectrum line has its origin is determined by the opacity of the sun's atmosphere, which in turn has been shown, by the calculations of Chandrasekhar and Breen,[19] to be a function of wave length. The opacity of the solar atmosphere in the visible and near infra-red is caused by photo-electric ionization of negative hydrogen ions; at longer wave lengths by free-free transitions of electrons in the fields of neutral hydrogen atoms. These effects result in a maximum opacity at about λ8,500, a minimum at λ16,600 and steadily increasing values as the wave lengths become longer. The 1.6 μ region of the spectrum should therefore be most favorable for observation deep into the solar atmosphere where

[14] Moore, C. E., *Atomic Energy Levels* I, Circular 467, Nat'l Bureau of Standards, 1949.

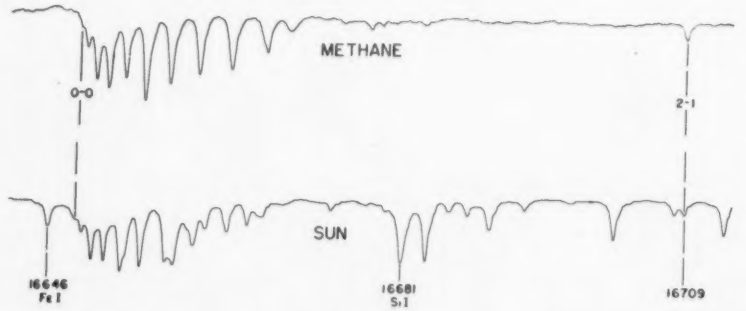
[15] *Festschrift für Elis Stromgren, Copenhagen,* E. Munksgaard, 1940.

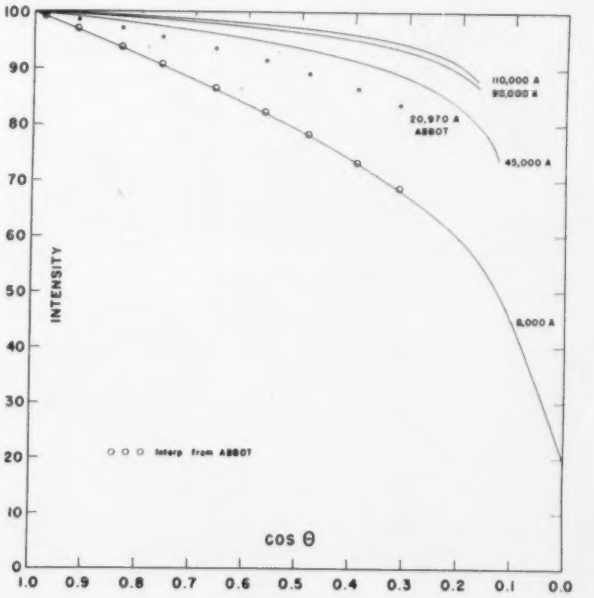
[16] Münch, Guido, Model solar atmospheres, *Astrophys. Jour.* **106**: 217, 1947; *ibid.*, The effect of nongrayness on the temperature distribution of the solar atmosphere, **107**: 265, 1948.

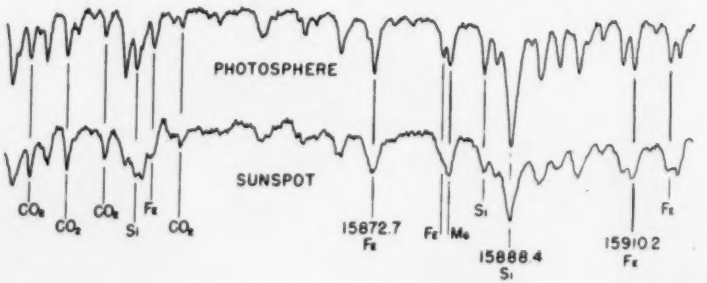
[17] Wildt, R., Electron affinity in astrophysics, *Astrophys. Jour.* **89**: 295, 1939.

[18] Abbot, C. G., *Am. Astrophys. Obs. Smithsonian Inst.* **1**: 1900–6, 1942.

[19] Chandrasekhar, S., and Frances Breen, On the continuous absorption coefficient of the negative hydrogen ion—III, *Astrophys. Jour.* **104**: 430, 1946.







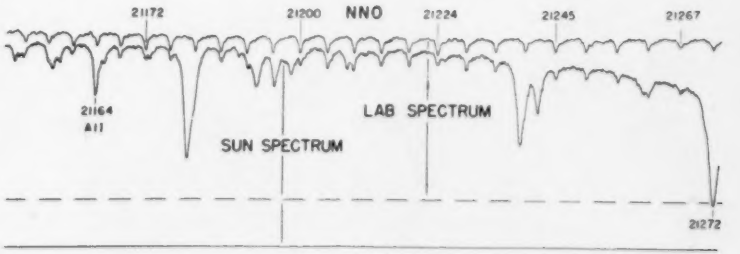


FIG. 5. *Upper left:* The spectrum of CH_4 in the laboratory, above, and in the earth's atmosphere, below. *Upper right:* Solar limb darkening in the infra-red. *Lower left:* Sunspot spectrum at λ15,800 as compared with that of neighboring disk. *Lower right:* The 2.13 μ band of N_2O in the earth's atmosphere and in the laboratory.

temperatures and pressures are relatively high. As we have noted previously, the energy states of the atoms are so arranged that the majority of infra-red atomic absorption lines originate from states of relatively high energy, and require high temperatures for their occurrence. Qualitatively these considerations seem to account for the notable deficiency of solar lines at 2.2 μ as contrasted with their relatively frequent occurrence in the 1.6 μ region. The higher pressures in the deep layers also act to widen and strengthen the lines at 1.6 μ, the broadening effects being enhanced by the high excitation potentials. Analyses of the intensities of the infra-red solar lines may therefore be expected to improve our knowledge of physical conditions deep in the solar atmosphere. The center to limb variations in the intensities of the infra-red lines form an important part of these studies.

SUNSPOT SPECTRA

The infra-red promises also to be a fruitful area for investigations of the spectra of sunspots. The most difficult observational problem here is to avoid contamination of the spot spectrum with radiation from the surrounding disk, which can be introduced by instrumental scattering, by bad seeing, or by poor guiding. The latter two effects are particularly serious when the spectrum is recorded by scanning rather than by the relatively instantaneous photographic process. A short section of a sunspot spectrum at λ15,800 is shown in figure 5, lower left. The purity of the spectrum is questionable in view of the smallness of the spot and the probability that a certain amount of radiation from the surrounding disk passed into the spectrometer. Nevertheless, the spectrum shows striking differences as compared with that of the neighboring disk. The conspicuous widening of the spot lines is probably due to the unresolved Zeeman splitting in the magnetic field of the spot. The widening of the lines is real, as is shown by the identical appearance of the telluric CO_2 lines in both spectra. It is likely that infra-red measurements of magnetic field strengths can be carried out with high accuracy, since the Zeeman effect is proportional to the square of the wave length. This advantage is partially reduced because of the fact that the theoretical resolving power of a grating, in wave length units, diminishes linearly with wave length. The variation of opacity with wave length may also make possible the measurement of magnetic field strengths at different depths in a sunspot region.

PROBLEMS OF THE EARTH'S ATMOSPHERE

To date the exploration of the infra-red solar spectrum has disclosed new bands of methane, of nitrous oxide, and of two isotopic forms of carbon dioxide. In addition, other previously known molecular bands have been resolved into individual lines. A large body of new observational material has therefore become available for the study of the properties of the earth's atmosphere. Analyses of the new data may be expected both to result in accurate determinations of the abundances of the atmospheric constituents, and to provide information on atmospheric temperatures and pressures. Significant variations in both abundances and temperatures may also emerge from long-range series of observations. The determination of abundance, temperature, and pressure is derived from the theoretical interpretation of the intensities of the absorption lines, guided by comparisons with laboratory spectra obtained with a measured quantity of gas at known pressure and temperature. Figure 5, lower right, shows a section of the 2.13 μ band of nitrous oxide in the solar spectrum as compared with the same series of lines produced in the laboratory by the equivalent of 76 mm. of N_2O at $\frac{1}{10}$ atmospheric pressure. A comparison of the two sets of intensities yields an equivalent atmospheric abundance for N_2O of about 4 mm. at atmospheric pressure and a temperature of 20° C.—about one part in two million of the volume of the atmosphere. A similar procedure applied to methane leads to an atmospheric abundance of about twelve atmo-mm. The value given here supersedes an earlier preliminary estimate of seventeen atmo-mm. The abundances of carbon dioxide and its isotopes are also being determined with precision and possible seasonal variations in the former are being investigated.

In conclusion, the authors wish to express sincere thanks to the trustees of McGregor Fund for the continued financial support that has helped to make possible the above investigation. The Office of Naval Research has also provided assistance for analyses of the solar data. Especial thanks are due to Mr. John Brodie for securing many of the observations, and to Mr. Russell E. Donovan for performing measurements and reductions of the tracings.

THE PORTRAITS OF ALEXANDER THE GREAT

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CONTENTS

PAGE

Acknowledgment 374
Introduction 374
I. The parents of Alexander and Alexander as crown prince 377
II. The conqueror of Europe and Persia (326–330 B.C.) 381
III. The Great King of Asia 384
IV. The period of the Diadochi (323–300) 388
V. The Alexandrian conception of Alexander (third and second centuries B.C.) 390
VI. The Asiatic conception of Alexander (second century B.C.) 392
VII. Late Hellenistic and Roman Republican conception (first century B.C.) 394
VIII. Conception during the Roman Empire (first to third century A.D.) 423
Conclusion 427

ILLUSTRATIONS AND SOURCES

FIGURE

1. Philip II, Medallion from Tarsus. *Revue Numismatique,* 4me série VII, pl. III, 1903.
2. Olympias, Medallion from Abukir. Dressel, *Goldmedaillons,* pl. II D.
3. Alexander and Olympias. Cameo in Leningrad. Bernoulli, *Darstellungen Alexanders,* pl. IX, 1.
4. Alexander and Olympias. Cameo in Vienna. Eichler-Kries, *Die Kameen,* pl. I.
5–6. Head of Alexander, Athens. Arndt, *Porträts,* pls. 475–476.
7–8. Head of Alexander, Musée Guimet, Paris. Arndt, pls. 922–923.
9. Head of Alexander Rondanini, Munich. Arndt, pl. 184.
10–11. Alexander Rondanini, Munich. Phots. Bruckman.
12. Alexander on Coin of Lysimachos. Phot. Boston Museum of Fine Arts.
13. Alexander, Azara Herm. Louvre. Phot. Giraudon.
14. Alexander, Azara Herm. Louvre. Ujfalvy, *Type physique d'Alexandre,* pl. II.
15–16. Alexander, Azara Herm. Louvre. Arndt, pls. 181–182.
17. Alexander, Azara Herm. Louvre. Phot. Giraudon 2051.
18. Alexander with the lance. Bronze Statuette, Louvre. Phot. Giraudon.
19. Alexander, Bronze Statuette, Grado. *Röm. Mitt.* 50, pl. 63, 1935.
20. Alexander with Aegis. Bronze Statuette, Cairo. *Mon. et Mém. Piot* 21, pl. V, 1913.
21. Alexander with Aegis. Statuette, Louvre. Phot. Giraudon, no. 2525, 1928.

FIGURE

22. Alexander riding on Bucephalus. Bronze Statuette, Naples. Phot. Alinari 11192.
23–24. Alexander riding on Bucephalus. Bronze Statuette, Naples. Arndt, pls. 479–480.
25. Head of Alexander, Dresden. *Athen. Mitt.* 63/4, pl. 15, 1938/9.
26. Alexander with thunderbolt. Neison Gem. Leningrad. Furtwängler, *Gemmen,* pl. 3, no. 11.
27–28. Alexander and Dareios. Details from Alexander Mosaic, Naples. Phots. Museo di Napoli.
29–31. Heads from Alexander Sarcophagus. From Sidon in Istanbul. Winter, *Alexandersarkophag,* colored pl. 17.
32. Alexander on Coin minted in Sidon, Newell Collection. Phot. American Numismatic Society (ANS).
33. Alexander on Coin minted in Babylon. *Athen. Mitt.* 63/4, pl. 3, no. 17, 1938/9.
34–35. Alexander on Coins of Ptolemy I. Phots. Museum of Fine Arts, Boston.
36. Alexander on Coin of Ptolemy I. Lange, *Herrscherköpfe,* p. 41.
37. Alexander on Coin of Lysimachus. Lange, *Herrscherköpfe,* p. 43.
38. Alexander, Statuette, Priene. Suhr, *Greek Statesmen,* fig. 12.
39–40. Alexander, Statuette, Priene. Ujfalvy, *Type Physique d'Alexandre,* pls. XII–XIII.
41. Alexander on Coin of Magnesia on the Meander, Newell Collection. Phot. ANS.
42–44. Head of Alexander. Stuttgart. *Expedition Sieglin,* II, 1B, pls. I–II.
45. Alexander on Coin of Lampsacus, Newell Collection. Phot. ANS.
46. Head of Alexander. British Museum. Phot. Mansell.
47–48. Head of Alexander. Cleveland. Phots. Cleveland Museum of Art.
49–50. Head of Alexander, found in Cos. Phot. Mus. Istanbul N 605.
51–52. Head from Cos restored. Phot. Berlin Museum.
53. Alexander on Coin 250–200. Phot. Mus. of Fine Arts, Boston.
54. Alexander on Coin, Giessen, Coll. Küster. Phot. Gertrud Küster.
55. Alexander on Coin from Cos. Phot. Berlin Museum.
56. Alexander on Gold Ring. Phot. Metropolitan Mus. of Art.
57. Head of Alexander from Pergamon. *Altertümer von Pergamon,* VIII, pl. XXXIII.
58. Head of Alexander from Pergamon. Phot. Museum Istanbul, N 423.
59. Alexander on Medallion from Abukir. Dressel, *Goldmedaillons,* pl. II C.

FIGURE

60. Fragment of Statue from Delos. Phot. Musée du Louvre.
61. Alexander on Coin from Priene, Newell Coll. Phot. ANS.
62. Alexander on Coin from Miletus, Newell Coll. Phot. ANS.
63. Alexander on Coin from Bactria, issued by Agathocles. *British Museum Cat. of Coins,* Bactria, pl. IV, 1.
64. Alexander on Coin from Mesembria in Thrace. *Revue Suisse de Numismatique,* **28**: pl. D, 1941.
65. Alexander, Statue from Magnesia. Phot. Mus. Istanbul, N 549.
66. Head of fig. 65. Phot. Mus. Istanbul, N 319.
67. Alexander on Coin from Macedonia, struck by Aesillas, Newell Coll. Phot. ANS.
68–69. Alexander, Head in Soli. *Swedish Cyprus Expedition,* III, pl. CLXIII, 1–2, 1937.
70–71. Alexander, Head in the Capitoline Museum. Bernoulli, *Darstellungen Alexanders,* pl. VII.
72. Alexander, Bronze Statuette, Cabinet des Médailles. Phot. Bibliothèque Nationale.
73. Alexander, Statuette, Louvre. Bernoulli, *Darstellungen Alexanders,* fig. 25.
74–75. Alexander, Porphyry Head, Louvre. Delbrück, *Porphyrwerke,* pl. 15.
76–77. Alexander, Head in Boston. Arndt, *Porträts,* pls. 481–482.
78–79. Alexander, Statue, Cyrene. *Notiziario Archeol.* II, pls. V–VI, 1916.
80–81. Alexander, Head in the Barracco Collection. Arndt, pls. 477–478.
82–86. Alexander on late Macedonian Coins. *Zeitschrift für Numismatik* **25**: pl. II, 1906.
87–88. Alexander on Medallions from Tarsus. *Revue Numismatique* **7**: pls. I–II, 1903.
89. Alexander on Coin of Elagabalus, from Apollonia Mordiaeum in Pisidia, Newell Coll. Phot. ANS.
90–92. Contorniates, Newell Coll. Phot. ANS.

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INTRODUCTION

Several monographs on the portraits of Alexander the Great have been written. They all contain some valuable material, but none of them is complete, and none has a satisfactory arrangement. The best monograph by J. J. Bernoulli, *Die erhaltenen Darstellungen Alexanders des Grossen,* München, Bruckmann, 1905, distinguishes between ethical and emotional portraits, which occur, however, in the same periods. Ch. de Ujfalvi, *Le type physique d'Alexandre le Grand, d'après les auteurs anciens et les documents iconographiques,* Paris, Fontemoing, 1902, treats in detail only of Alexander's actual appearance. Th. Schreiber, "Studien über das Bildnis Alexanders des Grossen, Ein Beitrag zur Alexandrinischen Kunstgeschichte, mit einem Anhang über die Anfänge des Alexanderkultus" in *Abhandlungen der sächsischen Gesellschaft der Wissenschaften* **21** (3), 1903, and more recently K. Gebauer, "Alexanderbildnis und Alexandertypus," in *Mitteilungen des Deutschen archäologischen Instituts* **63/4**: 1–106, 1938/9, deal particularly with those posthumous statues and heads which come from Alexandria. Gebauer distinguishes original and copies. E. G. Suhr, *Sculptured Portraits of Greek Statesmen,* with a special study of Alexander the Great, *The Johns Hopkins University Studies in Archaeology,* No. **13**: 46–133, 1931, makes the turn of the head to the right or left the distinguishing characteristic.

The main fault in all these monographs is the fact that none distinguishes between the different periods in which the bewildering varieties of Alexander portraits, preserved for us, have been created. It is a parallel to the mass of writers who have dealt with Alexander in antiquity as well as in our time. "There is no one about whom more have written, or more at variance with each other, says Arrian in his Preface to the *Anabasis of Alexander.* Yet he continues:

> But in my opinion the narratives of Ptolemy and Aristobulus are more worthy of credit than the rest; Aristobulus, because he served under King Alexander in his expeditions, and Ptolemy, not only because he accompanied Alexander in his expeditions, but also because being a king himself, the falsification of facts would have been more disgraceful to him than to any other man.

This critical use of his sources has made Arrian our soundest and most trustworthy source for the life of Alexander, despite the fact that he lived in the second century A.D. under Hadrian and Antoninus Pius. Plutarch, only a little earlier, for he is said to have been the teacher of Hadrian and died about A.D. 120, used the same sources, but also others less reliable, like invented speeches and letters of Alexander. His description of the

appearance of Alexander is based on the portraits made by the court sculptor Lysippos. We thus have in these Greek writers of the Roman period a parallel to the copies of contemporary portraits made mostly by Greek sculptors for the Roman masters. The original statues and paintings are mostly lost, but the copies are, like the writings of Arrian and Plutarch, so reliable that they can take their place. It is of course to be regretted that in both cases we do not have the originals. Ptolemy was the earliest and most intimate friend of Alexander, his most skillful general, who accompanied him throughout his campaigns and had access to the royal Ephemerides, the court journal of Alexander's expeditions and other official material. Aristobulus of Potidaea in Macedonia also accompanied Alexander as a technician and expert engineer, and he was interested in geography and natural history. Both works of these contemporaries, however, appeared only after Alexander's death and thus belong to the time of his successors, as many portraits do. Plutarch also used a contemporary account of Callisthenes of Olynthus, the historian who accompanied Alexander on his expeditions and who has been called his press agent. To him are due some extravagant inventions like the early deification of Alexander. But when he opposed the Persian custom of prostration to Alexander for Macedonians, and was connected with a conspiracy against Alexander, he was put to death in 327 B.C. His reports were partly used by Cleitarchus, a secondary source, as he did not accompany Alexander and as his history of Alexander was written probably in the early third century B.C. His romantic, rhetorical and sometimes bombastic style is therefore parallel and contemporary to the portraits which the successors of Alexander set up. From Cleitarchus stems the Alexander Romance, which we find in the early Roman writers Diodorus Siculus in his *Universal History, Book XVII,* from the time of Caesar and Augustus, and in Quintus Curtius Rufus, *De gestis Alexandri Magni,* from the time of Claudius, based on Trogus Justinus who wrote in the time of Augustus. Curtius also used other writers, particularly the "mercenaries source" based on tales of the Greek mercenaries, mostly refugees from their cities, who served in the army of Darius against Alexander. More unfavorable traits were brought from the philosophical schools, the peripatetic as well to which the executed Callisthenes, nephew and pupil of Aristotle, had belonged, and the stoic school, who conceived of Alexander as an arrogant and proud conqueror. They believed that it was Fortune alone which had led him to success, not his character. Two quite different literary character portraits are found in these sources: the perfectly virtuous pupil of Aristotle, and the later Alexander who became a cruel tyrant. Despite these exaggerations the distinction between the earlier and the later character of Alexander to me seems right in principle and a parallel to the distinction between the portraits of Alexander as a conqueror of Persia and as the Great King of Asia. Plutarch in his *De Alexandri Fortuna* has rightly protested against the distorted picture of the philosophers; he regarded Alexander as a philosopher in action. In his comparison of the Lives of Alexander and Caesar, he has shown how Alexander, despite impatience and irritability, by daring and bravery makes Fortune yield her power to his plans.[1]

We thus have in the ancient literature several portraits of Alexander which are partly contemporary, partly follow each other, and partly turn back to older pictures, but with newly invented traits. This, in my opinion, is to be expected in the art of the Alexander portraits also. It is quite clear that the young pupil of Aristotle looked different as crown prince and as commander-in-chief of the Greek army and again different when he became ruler of an enormous empire. We also know, particularly from Pliny, *Natural History,* Books XXXIV–XXXV, that different artists portrayed him at different periods. From childhood on he was portrayed by Lysippos; as a young general and crown prince he was portrayed, together with his father and mother, by Leochares. Euphranor and Chares or Chaereas also portrayed him at an unknown period, together with Philip. But while he was king he allowed himself to be portrayed from life only by Lysippos, Apelles, and Pyrgoteles. Nobody, however, could prevent the other artists from modeling, carving, or painting him, any more than he could prevent writers who were not invited to follow his expeditions, from writing about his deeds. Thus we know that Euthycrates, the pupil of Lysippos, sculptured Alexander as a hunter; Protogenes painted him with Pan; Aetion painted his wedding with the Bactrian princess Roxane. These pictures certainly belong to the period when he was on his expeditions in Persia, while paintings by Nikias

[1] Latest and best investigation of the literary sources: Tarn, W. W., *Alexander the Great,* II, Sources and Studies: 1–133, 286–309, Cambridge, Univ. Press, 1948.

and Antiphilos, who painted him as a boy, and another time with Philip and Athena, may belong to an earlier period. On the other hand Philoxenos of Eretria painted the battle of Alexander and Darius, commissioned by Krateros, certainly after the death of Alexander. An unknown artist painted the figure of the king in his chariot on his funeral carriage (Diodor, XVIII, 26). Many other portraits by unknown artists are mentioned. It is clear that the growing romance of Alexander's life must have inspired the artists still more than was the fact during his lifetime. Many rulers like Demetrius of Bactria, in the second century, Mithridates and Pompey in the first century B.C., and even Caracalla in the third century A.D. tried to imitate his appearance, transmitted by portraits. The Romans were the true heirs to Alexander's Empire much more than the diadochi who only carved portions out of it for themselves. But the Romans were really the rulers of the whole empire once conquered by Alexander and divided into states by his successors. The Romans were not only the political heirs, but also inherited his new ideas about the fusion of all mankind into one harmonious world, regardless of race and religion. Caracalla in A.D. 212 admitted all free inhabitants of the whole Roman Empire to citizenship, as Alexander had planned for the Persians and other non-Greeks, who up to this time had been considered, even by his teacher Aristotle, as "barbarians." We have here ideas which have been taken over by the Christian religion and which are brought into practice in our time only in the United States. The British, French, Belgian, Dutch, Portuguese, and all Empires still distinguish between subjects and citizens.[2]

No wonder that the personality of Alexander, his generosity and exuberant nature combined with conscious pose and deliberate action, his broad outlook and his romantic beauty, have enchanted writers, poets, and artists alike. He attracted the subtlest Greek and the rudest barbarian. His army and his Macedonian friends worshipped him as a hero even while he still lived. Although occasionally rebellious, they always followed him to his battles, not one of which he lost. His successes and the tragic losses of his friends, partly through his own fault, must have added to the attraction. No wonder that at all times new monographs were, and still are written on this greatest of all Greek historical figures;[3] and no wonder that again and again new portraits of him were created. The major ancient literary sources belong to four periods: (1) contemporary: Callisthenes, Ephemerides, Mercenaries; (2) time of the successors: Aristobulus, Ptolemy I, Cleitarchus; (3) early Roman, Caesar to Claudius: Diodorus Siculus, Curtius Rufus, based on Trogus Justinus; (4) second century A.D.: Plutarch and Arrian.

The figurative representations of Alexander, in my opinion, cover a longer space of time. They can give us a complete chronological picture of the development of the conception of Alexander from his youth to the end of antiquity. I have therefore tried to arrange all important portraits of Alexander in the following eight groups: (1) The parents of Alexander and Alexander as crown prince, to 336 B.C. Portraits made by the sculptors used by Philip. (2) 336–330 B.C. Alexander as conqueror of Europe and Persia. The three court artists. (3) 330–323 B.C. Alexander the Great, King of Asia, then identified with the Persian Empire. (4) 323–300 B.C. Alexander as conceived by the diadochi, his successors. (5) Third century B.C. Early Hellenistic, idealizing, particularly Alexandrian conception. (6) Second century B.C. Hellenistic, emotional, particularly Asiatic conception. (7) First century B.C. Late Hellenistic passionate and classisizing conceptions side by side. (8) Roman Empire. Continuation and increase of late Hellenistic conceptions.

The portrait of Alexander developed according to his life and to his personality, and later in accordance with the life story which the different periods composed out of the many different reports and also on the basis of older portraits available to them. Just as has been done for the literary periods, the different periods of art and different trends of each period have to be accounted for. The later artists interpreted the features of Alexander according to their own conception, just as the later writers added romance or scepticism to their older sources of contemporary

[2] Tarn, *op. cit.*, 399–449. Partly repeated from Alexander the Great and the Unity of Mankind, *Proc. British Academy* **19**: 123–166, 1933.

[3] Robinson, Jr., Charles Alexander, *Alexander the Great*, N. Y., Dutton, 1947. The Meeting of East and West in World Government and Brotherhood, 241–244. To his list of earlier works must be added, Droysen, J. G., *Geschichte Alexanders des Grossen*, 1833, new edition ed. H. Berve, 1931. Kaerst, Julius, in Pauly-Wissowa, *Real-Encyclopädie* I: 1412–1434, no. 10; *idem, Geschichte des Hellenismus* I², Leipzig, Teubner, 1927, and Tarn, W. W., *Alexander the Great* I, Narrative, 1948.

writers. We see many contemporary portraits only through their Hellenistic adaptations or their Roman copies, just as we know Ptolemy I and Aristobulus through Arrian, and Cleitarchus through Diodorus and Curtius. Yet a critical investigation will give us a clear picture of the portraits of each period.

I. THE PARENTS OF ALEXANDER AND ALEXANDER AS CROWN PRINCE

Philip II, the founder of the Macedonian Empire and father of Alexander the Great,[4] was the third son of Amyntas III, a rather insignificant king of a small state in northern Greece. The royal family, partly of Illyrian and partly of Hellenic blood, had always aspired, however, to Greek culture. When Philip was a young man of about fifteen, he was sent as a hostage to Thebes for three years (367–364 B.C.). He was further imbued with love for the higher form of civilization he found there. From then on he strove constantly to combine the warlike virtues of his people with the Hellenic culture.

Philip succeeded his two older brothers, first as regent for his infant nephew, then in 359 B.C. as king, at the age of twenty-three. He created the first national standing army organized on a broad basis. His most important addition to the infantry was the phalanx, a body of men in sixteen rows, the six front rows armed with long pikes. He first used this army to conquer all of northern Greece, the coasts near Macedonia, and Thrace. The siege of the Athenian colony Amphipolis in 357 brought him into conflict with Athens, a city which he venerated and always tried to pacify. But he needed the gold mines of the neighboring Mount Pangaeus; these provided him with the necessary means for attaining his political and military aims. He issued a new coinage which rivaled that of Athens, and his strong army and centralized political and financial control gave him superiority over the ineffective and vacillating policies of democratic Athens.

He then set out to conquer the Thracian Chersonese. The orator and statesman Demosthenes saw the danger and when Philip besieged Olynthus in 349, urged his compatriots to help. But they did too little and came too late; and Olynthus fell in 348 B.C. The *Philippics* and *Olynthiacs* of Demosthenes could not prevent Philip from becoming the strongest power in Greece, and the petty quarrels between the city-states gave him an excellent chance to attain a leading position. Isocrates, the great teacher of rhetoric, had prepared the way for him by calling for military and political unity under a strong leader, and the orator Aeschines was his most effective partisan. The Sacred War in 346 gave him the opportunity of defeating the Phocians and thus penetrating into central Greece and heading the Amphictyonic Council of Delphi. The Pythian games were celebrated under his presidency.

As champion of the Apollo of Delphi and patron of all Greece he was given leadership in the second Sacred War in 338, but instead of settling the Amphictyonic quarrel he used the opportunity to make himself definitely master of all Greece. Athens had hampered him in his siege of Perinthus and Byzantium in 340–339. He fortified Elateia, which threatened Thebes as well as Athens, and this led to an alliance between these two, till then, enemy states. But Philip won the decisive battle of Chaeronea. He cruelly punished his former ally Thebes, but his veneration for Athens, the center of Greek civilization, was so great that he gave to this city a good peace. In 337 at Corinth he called a congress of all the states, which were now to have a common national ideal of harmony, peace, equality, and prosperity for all under Philip's leadership. The envoys of the states at Corinth acknowledged Philip's military command and agreed to send contingents for an expedition against Persia. Philip intended only to conquer the coasts of Persia, but his plans were carried much further by his son Alexander, for Philip did not live to see his greatest dreams come true. At the wedding of his daughter Cleopatra at Aegae he was murdered by one Pausanias, perhaps at the instigation of his alienated wife, Olympias.

Several portrait statues of Philip are mentioned in literature. After the battle of Chaeronea the Athenians erected a statue of Philip in their market place in gratitude for the undeservedly mild peace terms (Pausanias, 1, 9, 4; Clemens of Alexandria, *Protrepticus*, IV, 54, 5; p. 42 Staehlin). Also after Chaeronea Philip dedicated the Philippeum at Delphi, in which gold and ivory statues

[4] Geyer, F., in Pauly-Wissowa, *Real-Enc.* XIX: 2266–2303, no. 7. Hogarth, D. G., *Philip and Alexander of Macedon*, N. Y., Scribners, 1897. Hampl, F., *Der König der Makedonen*, Weida in Thüringen, Thomas, 1934. Momigliano, A., *Filippo il Macedone*, Florence, 1934. Pickard-Cambridge, *Cambridge Anc. Hist.* II: 200–271. *Cp.* also Robinson, David, *Excavations at Olynthos*, in *Johns Hopkins Studies in Arch.* **6**, **9**, **11–12**, **18–20**, **25–26**, **31–32**; *passim*, 1933–1941.

of himself, his parents, his wife Olympias, and his son Alexander, by Leochares, were set up (Pausanias, V, 20, 10).[5] A third portrait, with one of his son, was by Chaereas (Pliny, XXXIV, 75). Another statue is mentioned in the account of the fatal marriage feast at Aegae; together with the statues of the twelve chief gods it was carried into the theater (Diodorus, XVI, 92, 2). A statue by Euphranor showed Philip and Alexander on a quadriga (Pliny, XXXIV, 78). There certainly were other statues at Pella and at Philippopolis, the city founded in 355 by Philip and named after him.

The coins minted by Philip do not show his portrait.[6] It is therefore impossible to determine the source of the only portrait of Philip that has been preserved on a medallion from Tarsus at the time of Alexander Severus, now in the Bibliothèque Nationale at Paris (fig. 1).[7] This shows the great general and statesman in a richly decorated corselet, with victories on the shoulder straps and breastplate; there is also a diadem which certainly he never wore. The hair and beard are full and curly. The forehead is furrowed, the eyes shaded, and the features are not purely Greek. It may be assumed that this conception is based on a posthumous portrait, perhaps set up by Alexander, who transferred his diadem to his father. This posthumous statue was probably the one erected in the temple of Artemis at Ephesus (Arrian, Anabasis, I, 17, 11) and pulled down in 334, a deed punished by death by the Ephesians after the arrival of Alexander.

The mother of Alexander the Great, Olympias, was the daughter of Neoptolemus of Epirus, king of the Molossians.[8] After the death of Neoptolemus her uncle became her guardian. He took her to Samothrace to be initiated in the Mysteries and on this occasion she met Philip of Macedon. They fell in love and were married in 357 B.C. The next year Alexander was born, and in 354 a daughter, Cleopatra. In 338/7 when Philip married another Cleopatra, the niece of the general Attalus, Alexander and his mother left the court of Pella. She remained in her homeland, Epirus, while Alexander went to Illyria and then returned to Pella. Olympias persuaded Philip to give their daughter Cleopatra in marriage to her young uncle, the heir to the throne of Epirus. At the wedding feast Philip was murdered by Pausanias, probably at the instigation of Olympias, who, with her daughter queen of the Molossians and her son king of Macedon, now hoped to play a leading role.

Olympias returned to Pella, killed Philip's second wife and her infant son, and was indeed a very influential mistress of the court until 331. Her son loved and respected her, though she behaved violently and obstinately and interfered in the concerns of others. The regent Antipater treated her badly during the absence of Alexander, and she therefore returned to Epirus to her daughter in 331. After the death of Antipater his successor Polyperchon called her back to Pella in 319 and made her guardian of her grandson, the little Alexander, son of Roxana. She killed the weak king Philip Arrhidaeus, his wife Eurydice, and a hundred other noble Macedonians, including Jollas, a son of Antipater. But Polyperchon was defeated and Cassander, another son of An-

[5] Overbeck, J., *Schriftquellen*, 251, no. 1312. Bieber, M., in Thieme-Becker, *Künstlerlexikon* XXIII: 68. Lippold, G., in Pauly-Wissowa, *Real-Enc.* XII: 1993–1997. For the Philippeum *cp.* Adler, F., *Olympia* II: 128–133. Gardiner, N., *Olympia*, 131–135, Oxford, Clarendon Press, 1925.

[6] Gaebler, H., *Die Münzen Nordgriechenlands* III, 2: 162–168, pls. XXX–XXXI, 17. Babelon, E., *Traité des Monnaies Gr. et Rom.*, ed. J. Babelon, part II, vol. IV: 499, pl. CCCIX, figs. 10–15, 1932. Seltman, Ch., *Greek coins*, 199–203, pls. XLVI, 7–14; XLVII, 1–4. Head, Barclay V., *Historia Numorum*, 223–224, Oxford, Clarendon Press, 1911. It has been supposed that the head of Apollo on the coins has been assimilated to the king and that the horseman on the coins may represent the king with a play upon his name. A certain identification is, however, impossible.

[7] Mowat, R., in *Revue Numismatique*, ser. 4, 7: 1, pl. III, 1903. Ujfalvi, Ch. de, *Le Type physique d'Alexandre le Grand*, 145, fig. 51, Paris, Fontemoing, 1902. Hogarth, *Philip and Alexander of Macedon*, plate facing p. 1. The interpretation of this coin portrait as that of Philip was first stated by Longperier in *Revue Numismatique* **13**: 313, 1868. This is doubted by Arndt, P., in *Strena Helbigiana*, 16, note 2. Arndt, P., *op. cit.*, 10–18, declares as Philip's the heads called Alcibiades in the Vatican (Arndt, P., *Porträts*, pls. 467–468) and in Munich (Arndt, P., *Porträts*, pls. 469–470; Arndt-Amelung, *E. A. ant. Skulpturen*, pls. 965–967); there is also a replica of this type in Copenhagen (Arndt, P., *Porträts*, pls. 1103–1104). But the head on these coins does not agree with that of the medallion which can hardly be of anyone but Philip, accompanied as it is by medallions showing the head of his great son. *Cp.* Babelon, E., in *Amer. Jour. Num.*, **44**: 119–121, 1910, *idem* in *Traité des Monnaies Gr. et Rome*, part II, vol. IV: 529–531, 1932. Babelon believes that the head of Zeus on the silver drachms of Philip (see Seltman, *op. cit.*, pl. XLVI, 10–12) is used for the medallion of Tarsus. The author believes that more likely a statue and not a coin was used in this case.

[8] McCurdy, Grace, *Hellenistic Queens, Johns Hopkins Studies in Arch.*, no. 14: 22–46, 1932. Strasburger, in Pauly-Wissowa, *Real-Enc.* XVIII (1): 177–182, no. 5.

tipater, came home to take revenge. He besieged Olympias in Pydna in 317–6, captured her, and brought her to trial. The relatives and friends of her victims acted as her judges and executioners.

The historians describe her as arrogant, meddlesome, fierce, passionate, dramatic, and romantic (Plutarch, *Life of Alexander*, IX; Arrian, *Anabasis*, VII, 12). She was an ardent follower of the orphic and bacchic mysteries. She had snakes as pets and let them wind around the sacred staff of Dionysus. From this predilection of hers probably comes the story of the god who approached Olympias in the shape of a snake and became the divine father of Alexander. The legend is represented on late Roman Macedonian coins.[9] Olympias is seated on a throne, with her himation drawn over her head and left shoulder, feeding a snake. The bust alone, with a similar arrangement of the drapery and only the right arm shown, appears on a golden medallion found at Abukir in Egypt (fig. 2),[10] on late contorniates of Macedonia of the time of Alexander Severus,[11] and on contorniates in Paris, Milan, and Berlin.[12] Olympias is represented with a diadem and scepter. The hair is carefully waved along her forehead. The profile is noble and regular. Around her right arm a living snake, not a stiff snake bracelet, is wound. The style is that of the second half of the fourth century.

There was a statue of Olympias at Delphi together with those of Philip, his parents Amyntas and Eurydice, and Alexander, by Leochares, erected after the battle of Chaeroneia in 338 B.C. The portraits on the coins and medallions may well derive from this statue of the great queen, and she may well have been portrayed with her favorite animal. The passionate nature and romantic beauty of the remarkable woman are not expressed in these late minor works of art, but they may be found as her legacy in the portraits of her son Alexander.

It has been thought that Olympias is represented with Alexander on the large cameos in Leningrad and Vienna (figs. 3–4).[13] This is possible, although the features are those of a younger woman and the identity of Alexander is not quite certain. The serpent on his helmet, however, may allude not only to his divine descent, but also to the serpent which is said to have guided him through the desert to the oasis of Ammon.

From his father, Philip, Alexander inherited his military virtues; from his mother, Olympias, he received his fiery and passionate nature, his ambition, his good looks, and romantic personality. Philip not only trained him in arms, but in 342 B.C., when Alexander was fourteen years old, his father gave him as teacher the most learned Greek of his time, Aristotle. Through Aristotle, the young Alexander was introduced to the culture, political life, and political theories of the Greeks, and intellectual force was thus developed in an excellent body. Aristotle made for Alexander a recension of the *Iliad*. Homer became his ideal and Achilles his hero to be emulated. He did not, however, accept all the teachings of Aristotle; the theory, for example, that all non-Greeks are barbarians and born only to be slaves was later refuted by him, both in principle and in practice, when he treated the subjected Persians as the equals of his Macedonians. He loved hunting, and is said as a boy to have tamed the wild horse Bucephalus after his father Philip had failed to do so. When only eighteen years of age he fought as a general in the battle of Chaeronea. In the quarrel of Olympias with Philip, it is interesting to note, he took his mother's side.

It is natural that the portraits of the young crown prince Alexander (340–336) were made by the artists used by his father Philip: Chaereas, Euphranor, and Leochares. Lysippos also is said to have made portraits of Alexander the Great,

[9] Gaebler, H., *Die antiken Münzen Nordgriechenlands* III, 1: nos. 347a, 416, 527, 529, 550–551, 634–636, 721a, pl. IV, 26–27. III, 2: nos. 35, 46, pl. V, 4–5. On other coins she is lying on a couch and greeting the snake. Gaebler, A., *op. cit.*, III, 1: no. 367, pl. IV, 35; III, 2: 13, no. 34, pl. V, 3. On contorniates with a similar representation there is the inscription "Olympias regina." *Cp.* Gaebler, H., in *Ztschr. für Numismatik* **25**: 13, 1906.

[10] Dressel, H., *Fünf Goldmedaillons von Abukir*, in *Abh. preuss. Akad. d. Wiss.* 10 and 31–40, pls. II, C, and IV, 7, 1906. Koester, E., Gold Medallions of Abukir, in *Burlington Mag.* **11**: 163, fig. 2, 1907. The authenticity of these medallions has been questioned, but there has not been proof of forgery. *Cp.* below, note 79.

[11] Sallet, A., *Ztschr. für Numismatik* **25**: 13, and 37–38, 1906. Ujfalvy, Ch. de, *Le Type physique d'Alexandre le Grand*, 87, fig. 26. Schreiber, Th., *Studien über das Bildnis Alexanders des Grossen*, 185, fig. 22. Gaebler, H., *op. cit.*, III, 1: no. 880. Probably not a coin but a piece of jewelry or an amulet. On the reverse side is a snake.

[12] Dressel, H., *op. cit.*, pls. III, 1 and IV, 1 and 8. On the contorniate at Paris, Dressel, H., *op. cit.*, pl. IV, 1, Olympias is represented as Omphale with a lion skin instead of the himation.

[13] Furtwängler, A., *Gemmen*, pl. 53. Bernoulli, J. J., *Darstellungen Alex.*, 126–131, pls. VIII, 1, and IX, 1. Delbrück, R., *Porträts*, pl. 58, fig. 15. Eichler-Kries, *Die Kameen*, pl. I.

beginning from his boyhood (Plin. XXXIV, 63). The earliest of the known portraits of the young Alexander is the prototype of the head of which three copies are now in existence, one in Athens (figs. 5–6), one in Erbach Castle in Germany, and one from Madytos in Berlin.[14] They show a youth fifteen to sixteen years old, which would indicate that the original was made about 340 B.C., when Alexander was a pupil of Aristotle. In this portrait he appears gentle, serious, and graceful. The curly hair stands up rather high on his head, while some strands hang down over the forehead and temples. The head has been attributed to Lysippos and to Leochares, but in style it differs from the work of either. It is closer to the latter, but does not correspond so closely as does the Alexander Rondanini (figs. 9–11), which has been rightly attributed to Leochares on account of its resemblance to the Ganymed and the Apollo of Belvedere.[15]

This Rondanini statue shows Alexander at about the age of eighteen, thus around 338, after the battle of Chaeronea, in which he distinguished himself as a young general. The cuirass behind him shows that he was a general. His left foot is on a shield. He may have held two spears and the hands may have been clasped loosely around the knee of the right leg, which, like the arms, is a bad restoration by Thorwaldsen. The body is unclothed like that of a hero, but the form is individualized. The chest is strong and broad, the limbs are heavy, the neck is carefully and richly modelled. The head shows marvelous energy coupled with a tinge of the romantic. The heavy hair is much more curly than in the other youthful portraits, a device probably used as an easy means of idealization. It rises in the front like a lion's mane, which was a characteristic peculiar to Alexander, as Aelian tells us (*Varia Historia*, XII, 14), while thick curls fall in the back and at the sides onto the neck. The lower part of the brow projects, the deep-set eyes are large and animated as he gazes into the distance. The nose is slightly bent and the mouth has a strongly marked individuality.

The romantic and highly idealized conception of the Rondanini statue is so nearly related in style to that of the Apollo of Belvedere, rightly attributed to Leochares, that it must be a work of this master. It could not, however, be a copy of the statue of Alexander set up, together with those of his parents and grandparents, on a semicircular base in the Philippeion at Olympia. These statues were of gold and ivory, therefore probably not naked but clothed and in an attitude of repose (Pausanias, V, 20, 9–10). The group showing Alexander hunting lions in Delphi was a work of a later period done by Leochares in collaboration with Lysippos (Plutarch, *Alexander* 40, 4). But Leochares undoubtedly produced other portraits of the youthful Alexander, perhaps for Athens or for Corinth. His conception was continued in some Hellenistic portraits, such as the head Guimet (figs. 7–8),[16] and on some coins of Lysimachus (fig. 12).

A third youthful portrait of Alexander has Lysippean characteristics. The best copy of this is from the Dressel collection in Dresden (fig. 25), while a similar head is in Copenhagen.[17] The age here is about the same as in the Munich statue. The main difference between this and the other portraits is that the thick hair, though similarly arranged, is straight, probably a realistic trait. The features in their careful modeling and somewhat nervous movement bear a close relation to the Apoxyomenos by Lysippos. The head is turned to the right, a characteristic pose of Alexander. It is undoubtedly by the same sculptor who made the original of the Azara herm (figs. 13–17). The straight hair is found also on the Alexander mosaic (fig. 27), the Neison gem (fig.

[14] Stark, K. B., *Zwei Alexanderköpfe*, pls. 1–2, 1879. Arndt, P., *Porträts*, pls. 473–476, 927–928. Bernoulli, J. J., *op. cit.*, 39–42, fig. 9, pls. II–III. Hekler, A., *Die Bildniskunst der Griechen und Römer*, pl. 63, Stuttgart, Hoffmann, 1912. Gebauer, K., *Athenische Mitteilungen* **63/64**: 70–71, 1938/1939. Blümel, K., *Katalog der Sammlung antiker Sculpturen Berlin* V: 7, K 203, pl. 17, 1938.

[15] Furtwängler, A., *Beschreibung der Glyptothek*, no. 298. Brunn-Bruckmann, *Denkmäler griech. und roemischer Skulptur*, pl. 105. Arndt, P., *op. cit.*, pls. 183–185. Hekler, A., *Bildniskunst*, pl. 61. Ujfelvy, Ch. de, *op. cit.*, pls. X–XI. Bernoulli, J. J., *op. cit.*, 44–51, fig. 10, pl. V. Gebauer, K., *op. cit.*, 72–73. Suhr, E. G., *Sculptured Portraits of Greek Statesmen*, 105–107, fig. 17. Laurenzi, L., *Ritratti Greci*, 105, pl. XV, no. 40. *Cp.* Bieber, M., in Thieme-Becker, *Künstlerlexikon*, XXIII: 68. Restored: piece in upper right part of head, both arms, right leg.

[16] Arndt, P., *op. cit.*, pls. 922–923. Gebauer, K., *op. cit.*, 44, K 22.

[17] Bernoulli, J. J., *op. cit.*, 42, pl. IV. Gebauer, K., *op. cit.*, 63, K 59, pl. 15. Suhr, E. G., *op. cit.*, 102–103, figs. 15–16. Hekler, A., *Bildniskunst*, pl. 60. For the portrait in Copenhagen see Poulsen, F., *Cat. Ny Carlsberg Glyptotek*, 310, no. 441, 1940. Arndt, *op. cit.*, pls. 471–472. L'Orange, H. P., *Apotheosis in ancient Portraiture*, 13–14, fig. 1. Oslo and Cambridge, Harvard Univ. Press, 1947.

26), and the coins issued later by Ptolemy I and Lysimachus (fig. 12; figs. 36–37; fig. 41).

Thus these early portraits, though not directly authenticated by inscriptions, have so many affinities with authentic likenesses that they give us a definite conception of the appearance of the crown prince Alexander. They give a picture of the unique qualities of the boy who combined the military virtues of his father with the romantic personality of his mother, and whose intellect was developed by Aristotle.

II. THE CONQUEROR OF EUROPE AND PERSIA (336–330)

When in 336 B.C., at the age of twenty, Alexander succeeded his father, he inherited a Macedonia that reached as far as the Balkan Mountains and the coast of the Aegean Sea, and included Thessaly; the rest of Greece, moreover, was dependent on Macedonia. He also inherited not only an army of about 60,000 men, but the League of Corinth, which had to be consolidated, and the grandiose plan of Philip to lead a Panhellenic war of revenge against Persia and to free the Greeks of Asia Minor. He first hurried through Thessaly to Greece, pacified Thebes and also Athens, which like his father he treated leniently, and had himself elected general of the League in place of Philip. In 335 he went north to the Danube, defeated the Illyrians and the Triballi and made an alliance with the Celts of the upper Danube to protect the Danube against the Getae, thus securing the northern frontier of his Empire. A report that he was dead fostered an uprising in Thebes and Athens. Thebes was destroyed—only the house of Pindar was spared—but Athens was again forgiven; Alexander desired to leave behind him a contented Athens when he went to conquer Asia.

In 334, as commander-in-chief of the Corinthian League, he crossed the Dardanelles with an army of 35,000–40,000 men. Antipater, the old general and friend of Philip, was left behind as governor in Macedonia and supervisor of the Greeks; Parmenio, another friend of Philip, was made second in command in Asia. While Parmenio fought against the Persian satraps of the coastlands and against the Greek mercenaries under Memnon, the Rhodian general of Darius, Alexander went to Ilium as a new Achilles and offered sacrifices in the old temple of Athena. On this expedition he was accompanied by philosophers like Callisthenes of Olynthus, the nephew and pupil of Aristotle, and by historians, geographers, botanists, and other scientists; later he was joined also by poets, artists, and actors.

In a wild and dangerous attack he won his first great cavalry battle on the river Granicus. As a result of this victory Alexander conquered in a short time all the Greek cities of Asia Minor, including Miletus and Ephesus, though with some of them he had trouble. They did not share his romantic enthusiasm for the free democratic government which he tried to institute everywhere, and the great warrior had to become an organizer as well. Ada, the sister of Mausolus, the satrap who died in 354, welcomed him in Caria and aided him against Memnon, who commanded Halicarnassus but fled to his fleet and died during the siege of Mytilene on Lesbos. After capturing Halicarnassus Alexander appointed Ada to act as Viceroy of Caria (Arrian, I, 23, 8). In 333 Alexander conquered all the coastal districts, as well as Lycia, Pamphylia, and Cilicia. In Tarsus he became ill but was cured by his physician Philippus. A letter from Parmenio had warned him that the physician wanted to poison him, but the generous and trusting nature of Alexander prompted him to drink the medicine given him by Philippus; and he recovered.

The decisive victory over Darius in the battle of Issus in 333 B.C. secured for Alexander the possession of all Asia Minor. The seizure of the treasure of the Persian king in Damascus put an end to the financial difficulties of Alexander. Leaving in Alexander's possession his chariot, his tent and his family, Darius fled toward the east. Alexander did not follow immediately, but went south along the coast. He besieged Tyre, the largest commercial seaport, and after seven months took the city in 332. Darius begged for surrender of his family, asked for peace and alliance, and even offered all his lands west of the river Euphrates, but Alexander proudly refused because he had already conquered that western part of the Persian empire. He now wanted all Persia, which was supposed to be all civilized Asia. In 332 he proceeded into Egypt, where he found little resistance, for Persian rule was hated there. He founded Alexandria on a well chosen site and destined to take over the commerce formerly handled by Tyre; as a result of Alexander's foresight it became the commercial center of the Levant, and has so remained to this day. While in Egypt, Alexander was crowned Pharaoh at Memphis and when he visited the sanctuary of

Zeus Ammon in the oasis of Siwah he was hailed by the priests, after the Egyptian fashion, as the son of Ammon-Re.

In 331 he returned to Asia and conquered the northern and the eastern provinces of the Persian Empire. The last battle between Darius and Alexander was fought at Arbela and Gaugamela, in Mesopotamia, near the Tigris and the ruins of Nineveh. Alexander attacked and won again under great personal danger. Darius again fled, this time to Media. Babylonia was the prize of the victory. Alexander now considered himself the Great King of Persia, and for the first time named a Persian, Mazaeus (Mazaios), as satrap of Babylon. He went to Susa, where he again found rich treasures, and then to Persepolis, the capital of Persia, which he destroyed in revenge for the destruction of Greek sanctuaries in the first Persian war a century and a half before. Here he again set up a Persian as satrap of Persia. He followed Darius to Ecbatana in 330, but before he could reach him Darius had been murdered by Bessus. Alexander sent the body to Darius' mother at Persepolis to be buried.

When Alexander became king he is said to have chosen the best artists of his time to portray him: Lysippos the sculptor, Apelles the painter, and Pyrgoteles the gem cutter. It is fortunate that the only inscribed herm of Alexander, found by the Spanish ambassador Azara in Tivoli, and now in the Louvre (figs. 13–17),[18] has a decidedly Lysippean character, which can be discerned despite the bad state of the surface.[19] The proportions agree with the head of the Apoxyomenos, though the subtleties of the movement of the muscles are lost in the superficial copy and its badly corroded surface.

The descriptions of the appearance of Alexander by Plutarch are admittedly based on the portraits of Lysippos:

> The outward appearance of Alexander is best represented by the statues of him which Lysippos made, and it was by this artist alone that Alexander himself thought fit that he should be modelled. For those peculiarities which many of his successors and friends afterwards tried to imitate, namely, the position of the neck, which was bent slightly to the left (in contrast to the turn of the head to the right), and the melting glance of his eyes, this artist has accurately observed [*Alexander*, 4, 1, p. 666b].

> For which Alexander gave to Lysippos the sole patent for making all his statues; because he alone expressed in bronze his character (ethos), and in his lineaments represented the lustre of his virtues; while others, who strove to imitate the turning of his neck and the liquid softness and brightness of his eyes were unable to preserve the manliness and lionlike fierceness of his countenance [*De Alexandri Magni Fortuna aut Virtute, On the Fortune or Virtue of Alexander*, II 2].

The turn of the neck and the hair standing up over the forehead like a lion's mane (anastole) are distinctly recognizable in the Azara herm, which is authenticated by the inscription of the shaft: ΑΛΕΞΑΝΔΡΟΣ ΦΙΛΙΠΠΟΥ ΜΑΚΕ(δων), Alexander, son of Philip of Macedon (fig. 13). There is a noticeable difference in the two sides of the face, and a certain Lysippean nervous play in the muscles and the hair are still recognizable, in spite of the fact that the herm is in a bad state of preservation. We must imagine the original as being much more delicately modelled, so as to bring out the small individual traits more accurately and with more feeling, and to express not only the character but also the mood of the great conqueror.

There can be no doubt that the head of this herm is a Roman copy of that of the most celebrated statue by Lysippos, the Alexander with the spear, of which Plutarch says (*De, Alex. Magn. Fort. aut Virt.* II, 2, 335 B):

> When Lysippos had finished the first statue of Alexander looking up with his face to the sky (as Alexander was wont to look, with his neck slightly bent) somebody not improperly added to the pedestal the following lines:
>
> The statue seems to look to Zeus and say,
> Take thou Olympus; me let earth obey!

A poem, *Anthologia Graeca Pal.* XVI (Plan. App. IV), no. 120, expresses a similar idea:

> Lysippos modelled Alexander's daring and his whole form. How great is the power of this bronze! The bronze seems to be gazing at Zeus and about to say: I set Earth under my feet; thyself, Zeus, possess Olympus.

[18] Louvre, *Cat. Sommaire*, no. 436. Bernoulli, J. J., *op. cit.*, 21–27, fig. 1, pl. I. Hekler, A., *Bildniskunst*, pl. 62 b. Arndt, P., *op. cit.*, pls. 181–182. Ujfalvy, Ch. de, *op. cit.*, pls. II, VIII, IX. Schreiber, Th., *op. cit.*, 17–40, figs. 4–5 (Inscription), pl. 1, Al. Suhr, E. G., *op. cit.*, 85–88, fig. 10. Laurenzi, L., *op. cit.*, 103–104, pl. XIV, no. 38. Restored: hair over left eye, part of eyebrows, nose, lips, part of herm. Surface much corroded.

[19] Johnson, F. P., *Lysippus*, 213–220, pls. 43–44; 298–309, nos. 52–74, 1927, valuable texts and translations of the references to Lysippus' statues of Alexander in ancient literature.

Fortunately there is a bronze statuette that agrees with this description and has the same long-shaped head and meager features as the Azara herm. It is the statuette in the Louvre, found in lower Egypt (fig. 15).[20] The head is turned sharply to his right, the left of the spectator; the neck is stretched and at the same time bent to his left, exactly as described in the literary evidence. The left arm is stretched out horizontally and probably held the spear, while the right hand points to the earth which Alexander had subdued by means of his spear, as expressed in the epigram. The statuette reflects the life and free movement characteristic of the works of Lysippos, and it is easy to imagine the lively impression of motion in the famous original statue from which it was taken.

This statuette is an early Hellenistic adaptation or reflection of the original, and the fact that it was found in Egypt points to the possibility that Lysippos has created the original for the city of Alexandria, founded by Alexander in 332. It has nothing of that tendency toward deification which began with Alexander's adoption by Zeus Ammon, and the literary evidence plainly indicates that Lysippos in the original was contrasting Alexander with Zeus, representing him as the conqueror proud of his own manly, not divine powers. The date of the original, therefore, must be before the year 330. This has been denied, however, on the ground that in the Azara herm Alexander appears to be about thirty years old, which would date the statue in 326 B.C. and that in this late period Lysippos could not have seen Alexander because he was then in India. But there is no reason why Lysippos should not have followed him to the East as other artists did. According to Plutarch (*Alexander*, 72, 1, p. 704E), many artists were summoned from Greece to Ecbatana. Probably Alexander's court sculptor was among them or had preceded them, and the statue of the great conqueror may well have been commissioned for the newly-founded city of Alexandria. As to Alexander's age, active military leaders age more quickly than ordinary men and he may well have been only twenty-five when the statue was made. Furthermore, he does not appear younger in the mosaic (fig. 27) which represents him in the battle of Issos, 333 B.C., and therefore only twenty-three years old.

Another statue by Lysippos showed him still younger. Alexander was only twenty-two years old when he won his first decisive battle on the river Granicus in 334. He himself impetuously rushed across the river into the violent cavalry engagement and was in the greatest danger, when Spithridates, the satrap of Lydia and Ionia, attacked him from the rear. His life was saved on this occasion by Clitus, but twenty-five of his companions (Hetairoi) fell in this battle. Alexander commissioned Lysippos to make their statues (Arrian, *Anabasis*, I, 16, 4) and to place a figure of himself among them (Velleius Paterculus, *Historia Romana* I, 11, 3–4). This group was set up in Dion in Macedonia but in 146 B.C. Metellus Macedonicus removed it to Rome. An adaptation of the figure of Alexander from this group made after this date, thus in the late Hellenistic or Roman republican period, is the statuette found in Herculaneum, and now in Naples (figs. 22–24).[21] The rudder under the horse alludes to the river, which Alexander crossed on horseback. The style of both horse and rider is that of Lysippos. The scarf of a general over his corselet shows that the figure represents Alexander. The broad fillet without hanging ends, however, is not the diadem, for Alexander did not adopt it till 330 B.C., that is, after the death of Darius, whose successor he claimed to be. The features of the face are youthful, the hair is only slightly curled, almost as straight as in the head in Dresden (fig. 25) and in the Azara herm (figs. 13–17), but it is more disheveled; on the forehead the locks are irregular and in the back they flutter to the sway of the lively movement.

Thus Lysippos conceived of Alexander as the great military genius and statesman of exceptional but human gifts. The epigram on the Alexander with the spear points to his conviction that he was a conqueror in his own rights as a man, not a god. Plutarch (*De Iside et Osiride* 24, p. 360D) contrasts Lysippos with the second court artist, Apelles: "Lysippos the sculptor blamed the painter Apelles for drawing Alexander's picture with a thunderbolt in his hand. He himself had represented Alexander holding a spear, which was

[20] Identified by Winter, F., in *Arch. Anz.*, **10**: 162, 1895. Johnson, F. P., *op. cit.*, 216–217, pl. 47. Bernoulli, J. J., *op. cit.*, 102–103, fig. 31. Gebauer, K., *op. cit.*, 65–66, K 61. Ujfalvy, C. de, *op. cit.*, 65, fig. 22. Schreiber, Th., *op. cit.*, 100–110, pl. VI, L. *Cp.* Bieber, M., in Thieme-Becker, *op. cit.*, XXIII: 498–499, s.v. Lysippos.

[21] Arndt, P., *op. cit.*, pls. 479–480. Bernoulli, J. J., *op. cit.*, 98–101, figs. 29–30. Ujfalvy, Ch. de, *op. cit.*, pl. XVII. Johnson, F. P., *op. cit.*, 225–226, pl. 48. Gebauer, A. K., *op. cit.*, 65–66, K 62. Markman, S. D., *The Horse in Greek Art, Johns Hopkins Studies in Arch.*, no. **35**: 102–103, fig. 60, 1943.

natural and proper for him as a weapon, the glory of which time would not rob him." This painting with the thunderbolt was created by Apelles for the temple of Artemis in Ephesus, and it is said that the finger of the hand seemed to project and the thunderbolt looked as though it were outside the surface of the picture (Pliny 35, 92). This perspective treatment of the hand and thunderbolt appears on the gem cut from a carnelian, now in Leningrad (fig. 26),[22] with a later inscription added by the owner Neison. This engraved gem may, therefore, be an early Hellenistic adaptation of the picture, though the addition of the aegis and the eagle points to a later period, after Alexander had been apotheosized (see below). The diadem also dates the figure not before 330, though the lean features and smooth hair agree with the earlier portraits. Apelles was probably the first artist to give Alexander the attributes of a god, a usage which later became general.

We have no means of deciding, however, whether the Neison gem and the many other Hellenistic gems with the portraits of Alexander [23] were not influenced rather by the work of the third court artist, the gem cutter Pyrgoteles, whose likenesses of Alexander are considered by ancient authorities equally as excellent and famous as those of Lysippos and Apelles (Pliny, VII, 125. Apuleius, *Florida* VII):

> Alexander was presented with singular excellence in all his likenesses; so that in all statues, pictures and engraved gems he appears with the same vigorous aspect of a most intrepid warrior, the same genius of a mighty hero, the same beauty and freshness of youth, the same noble expansion of forehead.

It may well be that the deification of Alexander had already been expressed by Apelles and Pyrgoteles, before this conception became general.

III. THE GREAT KING OF ASIA

The Macedonians in 330 B.C. believed the expedition of Alexander to be at an end. But the conqueror had no intention of leaving his new empire. Though he was still king of the people of Macedonia and leader of the Greek nation, he found the Oriental conception of monarchy much more congenial to his nature. He felt himself Lord of Asia and he now aspired to conquer the whole eastern world, which then was identified with Persia. Here began the last and most romantic, but tragic, part of his life.[24]

He started his campaign with the subjugation of the provinces to the south of the Caspian Sea; then he turned toward the northeast, to Bactria and Sogdiana, and reached the river Oxus. More and more he assumed the character of an Asiatic despot, even adopting the royal Persian dress.[25] This behavior led to quarrels with his Macedonians. The army became restless; his old friends were dissatisfied and could no longer understand him. Old Parmenio, already a general of Philip's and now Alexander's second-in-command, fell out of favor and his son Philotas, becoming involved in a plot against Alexander, was tried for treason and executed. Parmenio himself was killed on Alexander's order.

After having reorganized the army, Alexander crossed the Hindu Kush mountain range farther east into Turkestan, where he founded cities and appointed Persian satraps. He returned to Bactria, executed the rebel satrap Bessus, the murderer of Darius, and received reinforcements from Europe in 328. Again he crossed the Oxus and found near the river a spring of petroleum, which he was the first European to discover. He considered this a divine miracle and offered sacrifices to the unknown God that had bestowed it. He and Craterus, one of his generals, engaged in heavy fighting with Spitamenes of Sogdiana. Later another of Alexander's generals, Seleucus, married this prince's daughter, Apama, and founded the Seleucid dynasty.

In the summer of 328 Alexander had a quarrel with another Macedonian, Clitus, when both were drunk, and killed him in anger, despite the fact that Clitus had saved his life in the battle at the Granicus. Alexander repented bitterly, but the philosopher Anaxarchus assured him that kings could do no wrong. This among other things

[22] Furtwängler, A., *Die antiken Gemmen* I: pl. 32, no. 11; II: 157–158. Schreiber, Th., *op. cit.*, 205–207, fig. 25. Bernoulli, J. J., *op. cit.*, 133–134, pl. VIII, 3. Gebauer, K., *op. cit.*, 27, G. 31. Neuffer, E., *Das Kostüm Alexanders des Grossen*, 15, N 38. *Cp. ibid.*, other representations of Alexander as Zeus. On Alexander assimilated to several divinities see Tondriau, J., in *Revue de Philologie, de Littérature et d'Histoire anciennes*, 3rd sér., **23**: 41–52, 1949.

[23] Furtwängler, A., *Die antiken Gemmen*, I: pl. 31, nos. 16–17, 19–20; pl. 32, nos. 1–9; pl. 37, no. 23; II: 153, 157, 178. Gebauer, K., *op. cit.*, 25–32, G 1–58, pl. 4.

[24] Bevan, E. R., in *The Cambridge History of India*, ed. E. J. Rapson, I: 345–386, 1922. Tarn, W. W., *Alexander the Great*, I: 82–120. Robinson, Ch. A., *Alexander the Great*, 169–212. All are based for the most part on Arrian, IV 22–VI 28.

[25] Neuffer, E., *Das Kostüm Alexanders des Grossen*, 10–11, 30–38, Giessen, 1929.

contributed to Alexander's haughtiness and pride and encouraged him when in Bactria in 327 to try to adopt for his court the oriental custom of prostration before the royal presence. This most of his Macedonians resented, for although it was only the usual ceremony for Persians, when approaching the Great King, the Greeks interpreted it as worship. Anaxarchus, indeed, suggested that Alexander as descendant of Herakles should be gratified with divine honors, for there was no doubt that after his death he would be honored as a god. But Callisthenes of Olynthus, the nephew and pupil of Aristotle, who had earlier declared that Alexander was the son of Zeus, unexpectedly opposed. He said that Alexander was deserving of receiving the highest honors for humans, but not those reserved for gods. This is the same conception which Lysippos had, which, however, did not agree any more with the exalted position and mood of the Lord of Asia who received prostration from the most honorable Persians. Callisthenes, as a consequence, fell out of favor and, when involved in a conspiracy of Alexander's pages, died in prison (Arrian, *Anabasis* IV, 10–12).

In 327 Alexander captured the powerful Bactrian baron Oxartes and married his daughter Roxana, in order to reconcile the great eastern barons and end the costly war in eastern Iran. At the capital Bactra he ordered that native youths should be taught the Greek language and trained for his army. This army numbered now about 120,000 men.

He now set out to conquer the remaining portion of the Persian empire, India. His plans and ideas constantly grew with time and success of his expeditions. Only by and by the vastness of India was revealed to him and his scope of conquest and exploration became vaster and vaster. He first undertook to conquer the Punjab or land of the five rivers. It was ruled by several powerful rajahs. Alexander made an alliance with Taxiles, the rajah of Taxila, whose capital was a center of the Brahman religion and of commerce. Taxiles accompanied the army to fight against Porus, his personal enemy. The battle on the Hydaspes (Jhelum) River was a bloody one on account of the elephants used by Porus. Alexander treated the defeated and captured enemy like a king. His land as well as that of Taxiles became allied kingdoms. Alexander founded two cities on the river Hydaspes: Nicaea, victory town, and Bucephala, named after his horse (see figs. 22 and 27), which had died there.

While he was in India Alexander became more and more imbued with romantic ideas. When, for example, he found a site in which ivy was growing, near a city called Nysa, he thought it to be the sacred mountain of Dionysus. From now on he considered Dionysus a forerunner to his own visit to India. The sacred shield which he had taken from the temple of Troy was always carried before him in battles.

When he had reached the river Hyphasis (Beas) and when the army gazed across the plains extending to the far-away Ganges, which Alexander planned to reach, the soldiers revolted. They had been eight years in the field and now wished to end their labors and dangers and go home to their native land, not farther into unknown countries. Thus Alexander had to abandon the plan to find the eastern end of India, which he believed near. But he did stick to his resolve to sail down the Hydaspes and through the Indus River to the ocean, which he was convinced surrounded the earth. Before embarking in 326 on the Hydaspes Alexander standing on the prow of his ship offered sacrifices to his "ancestor" Herakles, to his "father" Ammon, to the gods of the Indian rivers and of the sea, and other gods. He then started down the river to the sea. Nearchos was admiral of the fleet, the army marched on both sides of the river. On his way he conquered several Indian cities. In the city of the Mallians, an independent tribe of Indians, he was in great personal danger. He went up the wall on a storming ladder and found himself alone except for three followers, one with the sacret shield. He was shot through the breast, but finally rescued by his army. This was the last of many wounds which he received during his expeditions, so that he could rightly say: "There is no part of my body in front at any rate, remaining free from wounds" (Arrian, VI, 10). His impetuosity and passion for glory was such that he could not keep aloof from danger.

Before reaching the Indus Delta, Krateros was sent westward through Arachosia to Carmania with the wounded and other soldiers no longer fit for military service. When he reached Patala, a city of the Brahmans at the beginning of the Indus Delta, he thought he had arrived at the southernmost edge of the inhabited world; for the Indian Sea he believed to be the ocean stream surrounding the earth. At the mouth of the Indus he built

a harbor and docks. Sailing out into the Indian sea he offered sacrifices to Poseidon and flung his golden libation cup into the sea, praying that the sea might bring Nearchos and his fleet safely home.

While Nearchos made his voyage through the Indian Sea to the Persian Gulf, Alexander himself marched with the army, through Gedrosia, in order to support the fleet by digging wells and forming depots of provisions on the coast. But his guides lost their way and for sixty days they all suffered from lack of water and food in the Gedrosian desert, Alexander sharing the hardships of his men, declining water when there was not enough for all. He finally reached Carmania, where he rejoined Krateros. The fleet landed after eighty days and the reunited army enjoyed feasts and athletic sports. In 324, with the army and the fleet, he returned to Susa, as the lord of Asia and the then known world of the Far East.

In Susa, Alexander settled the disorders which had broken out during his long absence. He put to death several faithless Persian satraps for governing badly, installed others, and reorganized his whole empire. The Macedonians were still the leading military power and the Greeks the leading cultural element; but Alexander strove more and more to weld together his Asiatic and European subjects into a great Macedonian-Persian universal Empire. He strove for a true unity between Macedonians and Persians. He broke with the classical Greek conception, that all non-Greeks were barbarians. He believed that harmony, peace and fellowship could reign among all men without regard to their race. He tried to attain this goal by a mass marriage at the victory feast in Susa for the conquest of the Persian Empire. Alexander himself married Barsina, a daughter of Darius, Hephaestion married her sister, and eighty officers married daughters of the Persian aristocracy; ten thousand of his soldiers married native women. Thirty thousand native youths who had received Macedonian training were now enrolled in the army.

This attempt to unite the Persians and the Macedonians into one world and to fuse the races and customs brought a revolt on the part of the Macedonians stationed at Opis on the Tigris. They were reconciled, and a banquet for nine thousand persons sealed the reconciliation. Alexander, however, sent ten thousand veterans back under Krateros who was to become regent of Macedonia, and asked the former regent Antipater to bring him new troops.

Not only the Macedonians, but also the Greeks of the mainland were by now discontent with the behavior of Alexander. He ordered the cities in 324 B.C. to take their political exiles back, which were numerous. As he had not the right to interfere with the internal affairs of the cities he requested that he be recognized by the Greeks as a god. This gave him the same unlimited authority in the Greek cities which he had in Egypt as the son of Ammon and in Persia as the Great King. It thus was a political not a religious measure. The cities of the League of Corinth granted him the honor, and it was probably at this time that the Corinthians set up a statue of Alexander as Zeus (Pausanias, V, 25, 1).

While the power of Alexander grew, he lost more and more friends. His best friend Hephaestion, the only one who had fully understood him, died in 324 at Ecbatana. When Alexander returned to Babylon in 323, he honored Hephaestion as a hero, providing a royal pyre and a luxurious funeral. He was full of plans for an Empire embracing Macedonians, Greeks, and non-Greeks, particularly the Persians, into a perfect fusion and harmony. He planned, by circumnavigating Arabia, to establish sea routes between India, Persia, and Egypt. He was now a recognized Empire ruler to whom ambassadors of the Greeks and of foreign people came with petitions on innumerable questions. But in 323, at the height of his glory, after a stormy reign of less than thirteen years, he died of fever. He had led a short life full of valor, and he left behind immortal glory. His last plans, the circumnavigation of Arabia and the exploration of the sea route between Mesopotamia and Egypt, the exploration of the Caspian Sea, the irrigation of Babylonia, and the draining of Lake Copais in Boiotia, could no more be carried through. They show his restless mind, his insatiable ambition to acquire fresh territory, to use new harbors, to colonize the seaboards and islands and to connect by sea all parts of his Empire, which he wanted to bind together as a political and cultural whole. These plans show indeed a genius at work, but his body was worn out too early. His ideas, however, lived on through the Hellenistic and Roman times, and were by and by realized.

The conception of his personality in the different periods is best reflected in his portraits.

It is very likely that the influence of Apelles and Pyrgoteles grew when Alexander began to aspire to the rule of a great unified Empire. This role called for his portrayal as an over-

human, divine personality, whereas Lysippos had always represented Alexander only as a supreme human conqueror. Lysippos seems to have received fewer assignments from Alexander at this period than before, for he was free to accept a commission of Krateros for a memorial of a celebrated lion hunt, in which Krateros had come to the rescue of the king in deadly combat with a lion (Plutarch, Alexander 40, 4). His collaborator in this group was Leochares, who must have been an old man at that time and probably also less in favor with Alexander than he had been with Philip. Leochares' part in the work was probably small, for Pliny (34, 64) names only Lysippos as the artist. There are only unreliable and weak copies of this work.[26]

Nor does any copy exist of any of the portraits of Alexander by Apelles either of his Alexander in a triumphal chariot, which later was on the forum of Augustus at Rome (Pliny, 35, 93–95), or of his Alexander on horseback at Ephesus, where the horse was so realistic that a real horse is said to have neighed at it (Aelian, *Var. Hist.* II 3). Yet a good idea may be gained of his art, his technique in four colors (white, yellow, red, black, and their mixtures, but no blue), his ethos, and particularly his conception of Alexander, from the mosaic copy of the battle of Alexander with Darius (Alexandri proelium cum Dario, Pliny, XXXV, 10) by Philoxenos of Eretria (figs. 27–28).[27] The painting was commissioned by Cassander, who became ruler of Macedonia in 317/6. It was probably done in Athens, brought to Macedonia and then taken to Rome with the booty of the battle of Pydna, 168 B.C., in which Aemilius Paullus defeated Perseus. Here it was copied, about 100 B.C., for the owner of the Casa del Fauno. It is probably a monument not of one battle, but of a combination of the heroic deeds of Alexander on the Granicus in 334, when he was in great personal danger, at Issos in 333, and at Gaugamela in 331, when he led his army in person against Darius, who had to abandon his chariot and flee for his life.

In this picture Alexander is still without a diadem. He is shown with straight, wild and dishevelled hair fluttering in the wind as a consequence of the rapid movement. His eyes are wide open in rage and violent emotion, and the eyebrows are contracted. The face is unduly lengthened, with long cheeks and chin. He has full lips. There is a sparse beard at the sides and the face in general is unshaven. Thus with the features drawn out of their normal form, the portrait cannot be used for determining Alexander's permanent characteristics. Yet it is a character portrait, showing the emotion and mood of the mighty conqueror under the tension of the moment. In the portraits by Apelles the king certainly was shown in far more ceremonious and serene majesty. But in this battle picture the details of the rich corselet, the weapons, and the harness of the horse Bucephalus, are so realistically depicted that it must be assumed they were based on the originals which could be studied in Athens or in Macedonia. In several points the style agrees with that reported for works by Apelles. The right hand of Alexander with the lance, and the right hand of the charioteer with the whip stand out of the surface as did the hand of Apelles' Alexander in Ephesus. The horse Bucephalus is so full of life and vigor that the story of how a real horse neighed at him in Ephesus might well have been told of this one too. Pliny (35, 88) says that the likeness in Apelles' portraits was so revealing as to be almost indiscreet. The same thing might be said of the ugly features of Alexander on the mosaic. It is in agreement with Alexander's later politics that Darius is treated with the same high esteem by the artist as Alexander. The Persian king is not thinking of himself but turns back to the friends who lay down their lives in order to enable him to escape.

Reflections of the art of Pyrgoteles, aside from gems, may be found in the first place on coins issued by Alexander, which in this period begin to

[26] Longpérier, A. de, in *Revue numismatique*, nouv. série **13**: 309, 1908, considers a medallion from Tarsus a copy of this work. See note 79. Loeschcke, G., in *Arch. Jahrb.* **3**: 190, pl. 7, 1881, publishes a bad relief from Messene as a copy of the group. *Cp.* refutation of this identification by Bernoulli, J. J., *op. cit.*, 152–153, and Fuhrmann, H., *Philoxenos von Eretria*, 243–244, 246–249. Room for the group and inscriptions: Courby, F., *Fouilles de Delphes* II: 237–240, figs. 187–191. Poulsen, F., *Delphi*, 291–292. Perdizet, P., in *Jour. Hell. Stud.* **19**: 273–279, pl. XI, 1899, considers a Hellenistic gem; Fuhrmann, H., *op. cit.*, 228–270 describes a mosaic in Palermo, fig. 9, pls. VIII–IX, and a sigillata goblet of M. Perennius, 245–247, fig. 10 as reflections of the group.

[27] Ujfalvy, C. de, *op. cit.*, pl. XVIII. Schreiber, Th., *op. cit.*, 73, fig. 11. Winter, F., *Das Alexandermosaik aus Pompeii*, Strassburg, Schlesier & Schweikhardt, 1909. Bernoulli, J. J., *op. cit.*, 31–32, fig. 4. Fuhrmann, H., *Philoxenos von Eretria*, Göttingen, W. F. Kaestner, 1931. Rostovtzeff, M., *Social and economic history of the Hellenistic World*, I: 128, pl. XVII, Oxford, Clarendon Press, 1941. Pernice, E., Pavimente und figürliche Mosaiken, in *Die Hellenistische Kunst in Pompeii* VI: 90, 1938.

lend the features of Alexander to the head of the young Herakles, the traditional obverse type of the Macedonian coins. It has been shown convincingly how the head of the ancestral hero was by and by remodelled to take the features of Alexander.[28] It seems to me that particularly the coins of Tarsus, Sidon (fig. 32) and Babylon (fig. 33) were meant to be idealized portraits of Alexander. The portraits on the coins were certainly not inventions of the different mints and certainly could not have been made from study of the king himself. They must have been dependent on works of art; of these, gems would have been much more convenient models for the profile views on the coins than sculpture in the round. The same is true of the coins of the following period. The conception of Alexander first as the descendant of Herakles and then himself as Herakles, or as son of Zeus Ammon and later as Zeus himself was probably much furthered by the two court artists Apelles and Pyrgoteles. These conceptions were much more in agreement with the taste of Alexander in his later years and with that of his successors, the diadochi, than the sober and intellectual conception of Lysippos. The achievements and designs of colossal dimensions in this period display a genius at work. It cannot be wondered at that Alexander not only believed himself under divine protection, and a descendant of Herakles, but in moments of exaltation he may have believed in, and boasted of divine origin. He is said by a late writer to have dressed occasionally as Ammon, Artemis, Hermes, or Herakles with lion's skin and club (Ephippos in Athenaeus XII, 537 e.f.). Nevertheless, he probably did not himself introduce his effigy on his coins, but allowed the head of Herakles to be made in his likeness. He did not have temples or altars in his lifetime. The swelling of the forehead, the fiery look and the excited tension which characterized the great conqueror are well rendered in the coins.

IV. THE PERIOD OF THE DIADOCHI (323–300)

Alexander's body was embalmed after his death, and taken first to Damascus, then by Ptolemy to Memphis, and at last to Alexandria. Here he reposed in a mausoleum in the center of the city at the intersection of two main streets. He left only one child, a son, by Roxana, born about the time of his death; but this boy, later named Alexander IV, was killed in 311 on the order of Cassander, the son of Antipater.

Alexander's life story crystallized more and more into a romance, and his deification progressed rapidly. In 324 he had demanded and received official deification from the Greek cities. This was not necessary in Egypt, where as a Pharaoh he was a god like his Egyptian predecessors. The priests of Ammon-Re had already proclaimed him as a son of this god in 332.[29] The successors of Alexander, who built their own power on the feats of the great conqueror, and the artists employed by them stressed more and more the divine character of the man.

Thus Abdalonymos, the king of Sidon, who owed his scepter to Alexander, represented him on the sarcophagus, which he ordered during his lifetime according to Oriental custom, with the lion skin helmet and with handsome, elegant features, in accordance with the Herakles coins of Alexander (fig. 32). These coins were issued probably during his last years or (like fig. 32) before October 320 and certainly then were interpreted as representing Alexander. The elongated cheeks, the protruding forehead, straight nose with slightly hanging tip, the full lips and the short, rounded chin are the same on the coins and the sarcophagus (figs. 29–30). This is usually known as the Alexander sarcophagus and is now in Constantinople.[30] It represents battles be-

[28] Seltman, Ch., *Greek coins, 212*: "the head of Heracles has frequently the features of Alexander himself." Hill, G. F., *Historical Greek coins*, 103, pl. VII, no. 59: "Head of young Herakles r., with features resembling Alexander's." Gebauer, K., in *Athen. Mitt.* **63/4**: 2–18, pls. 1–3, 1938/99. List of the articles of Newell, E. T., on the coinage of Alexander, in *ibid., 2*, note *2*. *Cp.* also Schreiber, Th., *op. cit.*, 164–167. Neuffer, E., *op. cit.*, 47–48. Seltman, Ch., *Greek coins*, 207–215, pls. XLVIII–XLIX. For coins minted in Babylon see Gebauer, K., *op. cit.*, 14–15. Our fig. 33 is taken from his pl. 3, fig. 17. The coins were minted 331–319 B.C. On coins with Alexander assimilated to Herakles, see Tondriau, J., in *Revue de Philologie, de Littérature et d'Histoire anc.*, sér. 3, **23**: 47–48, 1949.

[29] For the deification of Alexander: Neuffer, E., *op. cit.*, 11–21, 39–53. Robinson, C. S., Alexander's Deification, in *Amer. Jour. Philol.*, **64**: 286–301, 1943. Tarn, W. W., *Alexander the Great*, II: 347–374, 1948. Tondriau, J., *op. cit.*, 41–52, 1949.

[30] Hamdy Bey and Théodore Reinach, *Une Nécropole royale à Sidon*, pls. 25–30, Paris, Leroux, 1892. Winter, F., *Der Alexandersarkophag aus Sidon*, Strassburg, Trübner, 1912. Ujfalvy, C. de, *op. cit.*, pl. I, fig. 1. Bernoulli, J. J., *op. cit.*, 118–122, fig. 40. The connection with Abdalonymus and the coins first recognized by Studniczka, F., in *Arch. Jahrb.* **9**: 204, 226–227, 241–244, 1894; *idem*, Kunst an Kriegergräbern, in *Neue Jahrb.*, 309, 1915. For the coins of Tarsus *cp.* Newell, E. T.,

tween Greeks and Persians and hunting scenes. The large and radiant eyes of Alexander on the sarcophagus are similar to those of the Alexander Rondanini (figs. 9–11). Though the arrangement of the left part of the battle scene is similar to that of the mosaic (fig. 27) the mood is absolutely different. The features are calm with the exception of the eyes, to which the well-preserved color gives special life, a liquid gaze and a charming expression, but without great emotion. The head of Alexander in the lion hunt (fig. 31), represented on the other long side of the sarcophagus, is conceived in a still more idealized and typical manner than the one in the battle scene (figs. 29–30). It is to be noted that in both reliefs not Alexander but another person occupies the center of the stage. In the battle scene the central figure is probably Hephaestion, who had died before Alexander, and corresponding to Alexander at the right is an old general, perhaps Parmenio. In the lion hunt Abdalonymos himself dominates the scene in the center, while Alexander seems to be coming to his aid against the lion.

While this idealized and calm conception was probably derived from portraits made in the lifetime of Alexander, his immediate successors, the diadochi, turned to new conceptions and probably new artists for the now deified Alexander. The earliest coins minted from the beginning with the intention of presenting a real portrait of Alexander are those issued by Ptolemy I as satrap from about 318 B.C. (figs. 34–36).[31] They heap divine symbols on Alexander: the ram's horns of Ammon, the elephant's scalp of Dionysus, the aegis of Zeus. The elephant skin reminds at the same time of his victories in India. The diadem is laid like the fillet of Dionysos over the forehead. The features show fully developed Hellenistic style. But, although the lower part of the forehead is bulging, the eyebrows are drawn with an exaggerated angle, the nose is formed with a harsh break above its tip, the cheeks are strongly modelled, and the mouth is separated from them with sharp horizontal lines; yet the main individual features are the same as on the contemporary portraits: the large eyes, the elongated cheeks, the full lips, the tip of the nose, extended somewhat downwards, and the short rounded chin. The model for the coin portrait may have been the cult statue which Ptolemy erected at Alexandria in connection with the state cult for the founder of the city. Lysippos, whose Alexander with the spear probably stood in Alexandria, cannot have been the artist of the cult statue, and his work not the model of the coin, for he had refused to acknowledge or express the divine nature now attributed to Alexander, believing that Alexander's ingenious nature was enough to make him ruler of the earth. Furthermore, it can be assumed from the portrait of Seleukos in Lysippean style, that Lysippos continued to make realistic, not heroized portraits.[32]

The second conception of the deified Alexander is found on the coinage of Lysimachus of Thrace, beginning about 297 B.C. (figs. 12, 37, 41 and 45).[33] The only divine symbol here is the ram's

Tarsos under Alexander, in *Amer. Jour. Num.* **52**: 69–115, pls. I–VIII, 1918. Gebauer, K., *op. cit.*, 8–10, pls. 1–2, nos. 6–10; for those of Sidon, *ibid.*, 10–13, pls. 2–3, nos. 11–16. Our fig. 32 is in the Newell collection, American Numismatic Society, New York. It is dated before October 320 B.C. I owe the photograph and information to Agnes B. Brett.

[31] These first coins with the deified Alexander minted in Alexandria are dated by Svoronos, J., *Münzen der Ptolemäer* III: pl. I, 12–23; IV: 7–9, in 317–311 B.C. Gebauer, K., however, *op. cit.*, 14, 18–19, following Regling, K., dates already from 323. The tetradrachms in Boston, figs. 34–35, are dated about 318 B.C. Fig. 36 is from a coin belonging to the Berlin Museum. Lange, K., *Herrscherköpfe*, 42–43. Head, Barclay V., *Historia Numorum*, 848–849, figs. 373–374. Cahn, Herbert A., *Frühhellenistische Münzkunst* (Promotionsrede Basel, 1945), 13–14, figs. 10–11.

[32] See Johnson, Franklin P., *Lysippos*, 230–231, pl. 49. Arndt-Bruckmann, *Portraits*, pls. 101–102.

[33] Gebauer, K., *op. cit.*, 20–22. Bernoulli, J. J., *op. cit.*, 27–28, pl. VIII, 4. Hill, G. F., *Historical Greek coins*, 121–124. Imhoof-Blumer, 14, pls. I, 1; II, 1–3. Cahn, Herbert A., *op. cit.*, 20, fig. 19. Regling, K., *Die antiken Münzen*, 59–60, Berlin, 1929. *Cp.* the excellent evaluation of the coins of Lysimachus by Hinks, R., *Greek and Roman portrait sculpture, British Museum*, 9–10 to fig. 2b, 1935: "The coin-portraits of Alexander are less reliable as an iconographic guide than might have been expected. They are untouchable originals, it is true, but none are contemporary. The earliest and best is the noble head on the tetradrachms of Lysimachus, issued about twenty years after Alexander's death; yet this represents not the man but the divinized son of Ammon, as is shown by the ram's horns in the hair. It has been suggested that this beautiful head was borrowed from the gem by Pyrgoteles: certainly a great artist was responsible for it. Only the pose of the head, however, the expressive glance from the deep-set eye, and the mane of hair are the authentic marks of the Alexander types, and these general traits rather look back to the earlier conception of the Greek portrait as an ideal reconstruction, than suggest that Alexander's own effigies made an immediate contribution to Hellenistic portraiture."

For good enlarged illustrations of the Alexander coin portraits: Hill, G. F., *L'Art dans les Monnaies grecques*, 40, pl. IX, 1, 2, 4. Ujfalvy, C. de, *op. cit.*, 12, fig. 2; 122, fig. 36; 165, fig. 75. Lange, K., *Herrscherköpfe des Altertums*, 40–45, 1938. *Cp.* Head, Barclay V., *Historia*

horn of Ammon. The diadem is laid in the usual way, its ends and the full locks of hair fluttering in a most lively movement. The features are similar to those on the Alexandrian coins of Ptolemy I, but they are still stronger and the eyes are still larger to emphasize the marvelous intelligence of the great conqueror and Great King of Asia. This may reflect the influence of the gems of Pyrgoteles.

The excellence of these portraits indicates that in this period really great portrait statues of the deified Alexander must have existed, for in all times the Greek portraitist represented the whole figure, and not merely the head. On the reverse of some early gold staters of Ptolemy I, Alexander stands on a chariot drawn by elephants, clad in the aegis and holding a thunderbolt. In sculpture we have for this period only one statuette which, however, does give something of the greatness of the subject. The statuette, found in Priene (figs. 38–40),[34] is only one-third life-size, and only the upper part is preserved. But its high quality reflects the greatness of larger statues. It shows a strongly built man with the aspect and the muscles of an athlete. The left hand, found separately, probably held a sword. The hair is only sketchily executed, but it shows the "lion's mane" with the ends falling over the forehead. The features are similar to those on the coins issued by Lysimachos at Magnesia on the Maeander (fig. 41). They are also similar to later Ptolemaic coins, which are simpler than the earlier coinage. The nose of the Priene statue is too straight for accuracy. The eyes are deeply shadowed and the mouth is finely modelled. The statuette was found in a house of the third century, dedicated to the cult of Alexander, and may have been made around 300 or even soon after his death, for Priene had to be grateful to him for the funds he provided for the building of the large temple of Athena.

V. THE ALEXANDRIAN CONCEPTION OF ALEXANDER (THIRD AND SECOND CENTURIES B.C.)

Ptolemy I, Alexander's earliest and most intimate friend and one of his most skillful generals, became satrap of Egypt after the death of Alexander and king in 306; but he dated his reign from the death of Alexander, for whom he instituted an official state cult in the capital of Alexandria. He founded many Macedonian and Greek colonies in Egypt. Nevertheless, he won the confidence of the Egyptian inhabitants by his clever treatment and regard for their usages, monuments, and religious institutions. He made his capital, Alexandria, a center of art and industry and furthered science, philosophy, and literature. He founded the celebrated Museum, dedicated to the Muses, the largest library at that time. Thus art also flourished under him and his immediate successors.

At the magnificent tomb of Alexander in the royal quarter of the city of Alexandria a cult of the deified conqueror developed. Gradually Alexander became a god himself and was put on a level with Zeus. Just as in other Hellenistic sanctuaries small statuettes of the gods who were venerated there, were dedicated, particularly in sacred precincts of Asklepios and Aphrodite, so also in Alexandria many small and cheap figures of Alexander in soft limestone, with marble or limestone heads and stucco hair, were made and dedicated to him.[35] The first cameos carved with his portrait also seem to have been cut in Alexandria.[36] The two best and largest ones of those preserved, now in Leningrad (fig. 3)[37] and in Vienna (fig. 4),[38] were probably made there in the third century B.C. On these, as on the coins of Ptolemy, several attributes of gods were bestowed on Alexander, to lend more dignity to his

Numorum, 284–285, fig. 170. Our fig. 12 is in the Boston Museum, also used by Robinson, Ch. A., *Alexander the Great*, frontispiece. Our fig. 37 is in Berlin, Lange, K., *op. cit.*, 42–43. Our fig. 41 is minted for Lysimachus in Magnesia on the Maeander, and fig. 45 at Lampsacus in Mysia. These two coins are in the Newell Collection of the Amer. Numismatic Society. I owe the photographs to the kindness of A. B. Brett.

[34] Kekule von Stradonitz, R., *Sitzungsberichte der Berliner Akad.*, 280–288, 1899. Wiegand-Schrader, *Priene*, 180–182, figs. 176–177. Bernoulli, J. J., *op. cit.*, 58–61, fig. 15. Ujfalvy, C. de, *op. cit.*, pls. XII–XIII. Gebauer, K., *op. cit.*, 53–54, K 44. Suhr, E. G., *op. cit.*, 96–98, fig. 12.

[35] Schreiber, Th., *op. cit.*, 41–56, figs. 6–8, pls. I,B—III and IV, H. Bernoulli, J. J., *op. cit.*, 34–39, figs. 5–8. Watzinger, C., in *Expedition Sieglin* Vol. II, Part 1B: 1–7, nos. 1–3, figs. 1–2, pls. I–VI, 1927. Gebauer, K., *op. cit.*, 33–51, pls. 6–14. Arndt, P., *op. cit.*, pls. 921 and 926. Graindor, P., *Bustes et Statues-Portraits d'Égypte Romaine*, 73, pl. XXII, 1.

[36] Furtwängler, A., *Die antiken Gemmen* III: 155–156.

[37] Furtwängler, A., *op. cit.*, I, pl. LIII, 2; II, 251–252. Bernoulli, J. J., *op. cit.*, 126–130, pl. IX, 1. Maximova, M. I., *Cameo Gonzaga*, 1924.

[38] Furtwängler, A., *op. cit.*, I: pl. LIII, 1; II: 250–251; III: 151–152. Bernoulli, J. J., *op. cit.*, 130–131, pl. VIII, 1. Eichler-Kries, *Die Kameen im Kunsthistorischen Museum, Wien*, 47–48, no. 3, pl. I, 1927. Modern: neck and end of helm crest. Eichler interprets these portraits wrongly as Ptolemy II and Arsinoe II.

appearance. On the cameo in Leningrad he is shown with a helmet crowned with laurel and wearing the aegis. On the Vienna cameo his helmet is decorated with a snake, the thunderbolt, and the head of Ammon. The profile in both cases resembles that on the coins of Ptolemy but the expression is much softer and the modelling less vigorous. The head of the woman next to that of Alexander has been rightly interpreted as that of Olympias. On the cameo in Leningrad she is crowned with laurel, on that in Vienna, with a diadem decorated with an Egyptian lotos ornament and a veil. Her features resemble those on late contorniates of Macedonia and the medallion of Abukir (fig. 2). It was Olympias who had started the belief in Alexander's divine origin by her tale of the snake which had visited her. This probably was one of the reasons why she was allowed to share divine honors in Alexandria with her son.

Of the small heads of the third century from Alexandria, perhaps the best is the one now in Stuttgart (figs. 42–44).[39] It is similar to that of the cameos, but still softer in the peculiar Alexandrian manner, which is a development of the Praxitelean school. All transitions have been glossed over and vigor has given place to languor and delicate sentiment. The beauty of Alexander is stressed, and the melting look in his eyes noted by Plutarch. The masculine and leonine aspect, however, has disappeared, just as in the later Ptolemaic coins. A coin from Lampsacus in Mysia (fig. 45) dated 291/90 is similar in style for the face, but the hair is similar to the other Lysimachos coins (figs. 37 and 41).[40]

The largest and artistically best of the heads found in Alexandria is the one probably of the second century B.C. in the British Museum (fig. 46).[41] It has the bend of the neck, the melting look of the upturned eyes, a thick mass of curled hair, which, however, lacks the arrangement of upraised hair of a lion's mane, and instead hangs rather long over the forehead. Its authenticity as a head of Alexander has been doubted, but it does probably represent the great conqueror divinized, with his outward appearance idealized to suit the conception of deification. That Alexander's real features have been modified and become blurred is also obvious from the fact that the bending of the neck and the turning of the face are in directions opposite to those attested by literature and by copies of contemporary portraits.

Another large head from Alexandria, now in Cleveland (figs. 47–48),[42] shows similar beautiful features, but they are marked by an even greater softness. The liquid glance of the eyes is still present, and the mouth is opened with an expression of yearning. The cheeks and the parts around the mouth are subtly modelled. The richly curled hair has traces of red, which indicates that it was probably painted reddish blond. The back and sides of the head were modelled in stucco after the Alexandrian fashion. This technique has contributed still further to the softness and tenderness of surface execution.

Another idealized portrait of Alexander from the island of Cos, now in Constantinople (Istanbul, figs. 49–50),[43] about one-third more than life-size, seems to represent Alexander as saviour. This head was found on a terrace dedicated first to Apollo and later to Asklepios. With it were found fragments of a statue to which it belonged, now lost. It was probably the one beheld in the second century by Nikander, as reported by Karystios of Pergamon (in Athenaeus XV, p. 684 E), who saw the ambrosia plant, a symbol of immortality, growing on the head of the figure. Such a plant might well have taken root in the eye-opening of the now lost helmet (*cp.* reconstruction in figs. 51–52).[44] This helmet must have enhanced the effective framing of the face by the sharply twisted long curls of the hair. The com-

[39] Schreiber, Th., *op. cit.*, 45–52, pl. II, C. Bernoulli, J. J., *op. cit.*, 37–39, figs. 7–8. Watzinger, C., *op. cit.*, II: 1–2, pls. I–III. Suhr, E. G., *op. cit.*, 100–101, fig. 14.

[40] For the Ptolemaic coins see Svoronos, J., *Die Münzen der Ptolemäer* III: pl. I, 12–23; IV: 7–9. Our fig. 45 is a coin from Lampsacus in the Newell Collection of the American Numismatic Society. I owe the photograph to Agnes B. Brett.

[41] Schreiber, Th., *op. cit.*, 45–46, 51–52, pl. II, D. Bernoulli, J. J., *op. cit.*, 62–65, pl. VI. Ujfalvy, C. de, *op. cit.*, pl. XIV. Hinks, R., *op. cit.*, 9, pl. 9, *British Museum Catalogue of Sculpture* III, no. 1857. Suhr, E. G., *op. cit.*, 98–100, fig. 13. Gebauer, K., *op. cit.*, 38–39, K 9; he discusses this under his earlier group, though dating it later. Laurenzi, L., *Ritratti Greci*, 126, pl. XXXIV, no. 86, Florence, Casa Editrice Sansoni, 1941.

[42] Gebauer, K., in Arndt, *op. cit.*, pls. 1201–1202; *idem*, in *Athen. Mitt.* **63/64**: 44, K 23, 1938/9. He dates it in the second century B.C. Bieber, M., *Art in America*, 121 and 124, fig. 13, 1943.

[43] Bieber, M., in *Arch. Jahrb.* **40**: 167–182, pls. 6–8, 1925. Gebauer, K., in *Athen. Mitt.* **63/64**: 58–59, K 48, 1938/9. He dates it at the end of the second century. Tondriau, J., in *Revue de Philologie* **23**: 48, 1949, wrongly quotes me as having named this head Alexander as Herakles.

[44] Reconstruction by Bruno Schröder. *Cp.* Bieber, M., *op. cit.*, 172–173, figs. 5–6.

plicated movement of neck and head is much emphasized. The features are in simple and large planes, but richly modelled in detail. Thus there is a deep hollow between the rounded chin and the full lower lip. The upper lip is beautifully curved. The well preserved nose is broad and straight, and sharply divided from the cheeks. The eyes are noble in character, with deep corners, and the transition to the cheeks is delicately handled. They are large, wide open, and gazing upward with an expression of deep feeling. The forehead protrudes over the eyebrows. The forms here are more solid than those in the heads from Alexandria and more in the tradition of the youthful portraits of Alexander, though not so close to the latter in spirit as is the almost contemporary head in the Musée Guimet (figs. 7–8).[45]

All these heads show that the tradition of idealization was prevalent during the third century and still partly in the second century. This tradition is also noticeable on coins, for example on the coins of the island of Cos, particularly one now in Berlin, with the name of the magistrate Klymenos,[46] which shows the lion's scalp on the head. Another coin from Cos, in Berlin, has the head wearing the lion's skin in three-quarter view (fig. 55) and it agrees with a portrait on a gold ring in the Metropolitan Museum (fig. 56) in such a remarkable way that some connection between the two must be assumed.[47] On the coins of Cos the youthful Herakles takes the place of the bearded Herakles, and there is no doubt that—as on the late coins issued by Alexander—Herakles was interpreted as showing the features of Alexander. The same is true on a coin in Boston, dated 250–200 (fig. 53), and a similar one in Giessen, in the possession of Gertrud Küster (fig. 54).

In the later coins of the Ptolemies the heads of Alexander tend to lose their portrait character, just as the coins of the later Ptolemies with the head of the first Ptolemy became conventional repetitions of the older coins. The same is true for the Alexandrian marble heads of Alexander, which tend to lose their portrait character. Some of these may have belonged to statuettes of Alexander with the aegis of Zeus as defensive armor (figs. 20–21).[48] They probably have been rightly explained as private dedications by Macedonian soldiers to Alexander. The characteristic features of the great conqueror, however, have been lost in these insignificant gifts of unartistic donors.

VI. THE ASIATIC CONCEPTION OF ALEXANDER (SECOND CENTURY B.C.)

The fate of the different Greek states—and with it their art—changed during the second century B.C. in some to the worse, in others to the better. The influence of the growing power of Rome made itself felt everywhere. Egypt under the later Ptolemies, who were much weaker than their predecessors, had to accept the Roman senate as guardian. The Romans interfered also in Asiatic politics. After they had defeated Antiochus III in the battle of Magnesia in 190 B.C., Syria was struck from the list of great powers. On the other hand, the able Attalids, who sided with the Romans, increased their territory and might. Bactria gained supremacy in central Asia and even ruled for a while in the Punjab in India, which had once been invaded by Alexander. The rulers of all these states continued to consider Alexander as their ideal model and forerunner.

Therefore, while the Alexandrian school decayed, the Asiatic school of sculpture flourished in the second century, particularly under the Attalids at Pergamon. The head of Alexander which was found there and is now in Constantinople (figs. 57–58) [49] may be assigned to the period of the great altar built by Eumenes II (197–159). This grandiose and impressive head may have been based on a portrait made during the last years of Alexander, when hardship and trial—particularly the campaign in India, the retreat through the desert, the revolt of his army, and the loss of his best friends—had worn out his body, ravaged his features, furrowed his brow prematurely, and laid deep shadows around his

[45] See note 16.

[46] Bieber, M., *op. cit.*, 178, fig. 10b.

[47] I owe the photograph of the coin to Professor Rudolph Herzog; of the gold ring to Dr. Gisela Richter. She will publish this ring in her Catalogue of Gems. Mus. No. 10, 132, 1. Similar coins from Cos, *British Museum Catalogue of Greek Coins, Caria and Islands*, 200–204, pl. XXXI, 13–19, dated *ca.* 190–166? Regling, K., *Die Münze als Kunstwerk*, 137, no. 864, pl. XLII, dates *ca.* 200 B.C.

[48] Perdrizet, P., in *Monuments et Mémoires Piot* **21**: 59–72, figs. 1–7, pls. IV–V, 1913. Schreiber, Th., *op. cit.*, 138–139, 142–145, pl. XII. Gebauer, K., *op. cit.*, 77–78, 104–105, K 77.

[49] Winter, F., *Altertümer von Pergamon* VII, 1: *Skulpturen*, 147–149, no. 131, Beiblatt 21, pl. XXXIII. Bernoulli, J. J., *op. cit.*, 80–82, figs. 23–24. Hekler, A., *Bildniskunst*, pl. 59. Ujfalvy, C. de, *op. cit.*, 174–178, pl. XXII, figs. 77, 81–82. Bieber, M., *op. cit.*, 180–181, fig. 11. Gebauer, K., *op. cit.*, 56–57, K 47. Laurenzi, L., *Ritratti Greci*, 126, pl. XXXIV, no. 87.

eyes. Similar signs of premature aging may be seen today in the faces of young veterans of modern warfare. The cheap expedient of achieving idealization by curling the hair is scorned. Alexander is shown with straight hair as in the Azara herm and the mosaic (figs. 13–17 and 27). The expression is full of pathos and of pothos, that is that passionate and ambitious longing which had driven Alexander farther and farther into the unknown East until he had reached what he believed was Oceanus, the boundary of the inhabited world. The "lion's mane" and the movement of the neck may have been derived from a portrait by Lysippos, but the conception is in the vein of the purely Hellenistic emotion, the so-called baroque.

A similar romantic conception of Alexander as Lord of Asia and the conqueror of India in a rather baroque style may also be seen in coins of the first half of the second century, thus in the coins of Priene minted about 200–190 (fig. 61), in those of Miletus, minted about 190–170 (fig. 62), in those of Agathocles of Bactria, who was king of northwestern India about 170–150 (fig. 63), and the rare coin of Mesembria in Thrace, inscribed with the signature of the artist ANT on the lion's scalp above the paw, minted about 150 B.C. (fig. 64).[50] The same conception and the same baroque spirit was later taken over by the Romans, who considered themselves rightly heirs to the empire of Alexander. Even as late as the third century of the Christian era a head of the Pergamon type was used on a gold medallion of Abukir (fig. 59, see below).

The statue to which the head in Pergamon originally belonged may have been a Hellenistic adaptation of a statue by Lysippos. A bronze statuette in Grado near Aquileia (fig. 19) seems to be a Roman copy of such a Hellenistic emotional remodeling.[51] As in the Louvre statuette (fig. 18) it held a spear in the left hand, had its head turned and raised and the feet in a walking position. But the attitude has much more swing and passion than the Louvre statuette. The head is turned much more and lifted to the left instead of the right. The body has a strong bow-like curve. In addition to the spear in the left hand a sword with scabbard is carried in the right hand, and a small chlamys is wound around shoulders and left upper arm. From this statuette it is possible to gain an idea of the essential character of a second-century statue of Alexander.

A late second-century statue of Alexander from Magnesia, now in Constantinople (figs. 65–66),[52] has the same attribute of a sword, which, however, is already found on the Neison gem (fig. 26) and in the statuette from Priene (figs. 38–40). The date for the Magnesia statue is derived from the forms of the letters in the inscription found with the statue, which bears the signature of the artist Menas of Pergamon, and it is corroborated by the powerful and realistically free arrangement of the himation. The body is broad and strong. The full hair was adorned with a bronze wreath. The features are softer than those of the head from Pergamon (figs. 57–58). They are idealized and even less individual than those of the head from Cos (figs. 49–52). The expression of longing in the eyes and mouth has been toned down. It is Alexander conceived as an Apollo.

Also to an idealized likeness of Alexander of the late second century may possibly be ascribed a fragment found in Delos, now in the Louvre, the so-called Inopus (fig. 60).[53] It may, on the other hand, be one of the many creations conceived under the influence of the heroized and deified portraits of Alexander. Its date must be around 100 B.C.

[50] The coins, figs. 61–62 from Priene and Miletus are in the Newell Collection, American Numismatic Society. *Cp.* for coins of Priene with Alexander: Regling, K., *Die Münzen von Priene*, 37–44, pl. II, 32–39; III, 40–43, Berlin, Schötz, 1927. Coin of Agathokles of Bactria: Gardner, Percy, ed. R. S. Poole, *British Museum Catalogue of Indian Coins, Greek and Scythic Kings of Bactria and India*, XXVIII–XXIX and 10, pl. IV, 1, 1886. *Cambridge Anc. Hist.*, volume of plates II: 10–11, no. c. Schreiber, Th., *op. cit.*, 176–177, fig. 19. Regling, K., *Die ant, Münzen*, 56–57, Berlin, 1929.

Coin of Mesembria in Thrace, in the Ros Collection, Zurich. Lederer, Ph., Ein Beitrag zum Münzbildnisse Alexanders des Grossen, in *Revue Suisse de Numism.* **28**: pl. D, Bern, 1941. I owe the photographs of these four coins to Agnes B. Brett.

[51] Lorentz, Fr. von, in *Röm. Mitt.* **50**: 333–347, pl. 63, 1935. L'Orange, H. P., *op. cit.*, 26, fig. 10.

[52] Hekler, A., *Bildniskunst*, pl. 64. Reinach, Th., in *Monuments et Mémoires Piot* **3**: 155–165, pls. 16–18, 1897. Ujfalvy, C. de, *op. cit.*, 97, fig. 28, pl. VII. Bernoulli, J. J., *op. cit.*, 53–58, figs. 12–14. Schede, M., *Meisterwerke zu Constantinopel* II: pl. 19. Gebauer, K., *op. cit.*, 59–60, K 49. Laurenzi, L., *op. cit.*, 125–126, pls. XXXIII–XXXIV, no. 85.

[53] Bernoulli, J. J., *op. cit.*, 88–89, fig. 27. Michon, Etienne, *Bull. corr. Hell.* **35**: 288–301, pl. 10, 1911. Gebauer, K., *op. cit.*, 46, K 28. Dickens, G., *Hellenistic Sculpture*, 26, fig. 20. Suhr, E. G., *op. cit.*, 110–111, fig. 19.

VII. LATE HELLENISTIC AND ROMAN REPUBLICAN CONCEPTION (FIRST CENTURY B.C.)

The growing power of the Romans was challenged for the last time in the first century B.C. by Mithridates VI, Eupator, of Pontus, the last great male Hellenistic ruler. He had in 100–99 conquered Paphlagonia and Bithynia, but the mighty Roman senate forced him to give up the two states. This made him a most dangerous enemy of Rome. With the help of his son-in-law Tigranes of Armenia he again conquered Bithynia and also Cappadocia. The exiled kings asked the Romans for help and this led to the three so-called Mithridatic wars (88–84, 83–81 and 74–64 B.C.). Mithridates had travelled all through Asia Minor and knew that the Greek cities there suffered under the harsh Roman rule. He came to them—as once Alexander had done—as a liberator. With their help he conquered the whole of Roman Asia, and killed not only all Roman prisoners, but had about 80,000 citizens murdered. The Greeks honored him with many statues, and he minted silver tetradrachms with his portrait. These coins and some portraits identified on the basis of these coins show an energetic and passionate expression. Coins minted in Odessus imitate the coins of Lysimachus (see figs. 12, 37, 41) only the features of Alexander are replaced by those of Mithridates. On these coins and in a head in the Louvre as well as in a statuette in Pergamon [54] he is represented with the headdress of a lion skin, the anastole, rising of the hair over the forehead, the romantically floating hair and the exalted expression of some of the Alexander portraits. The lion skin was taken by Alexander as a symbol of his descent from Herakles. Now Mithridates considered himself, like Herakles, a benefactor of mankind, engaged in liberating it from evil. There is no doubt that he felt himself a genuine heir and even a kind of reincarnation of Alexander.

It is interesting to note that Pompey, the Roman general who in 66 B.C. won the final victory over Mithridates, not only like his enemy and like Alexander received the surname the Great, Pompeius Magnus, but also like Mithridates tried to imitate Alexander the Great. He wore his hair in the anastole, he furrowed his brow and he looked up like Alexander (Plutarch, *Pomp.* 2. Velleius Paterculus 2, 29). This attempt of imitating Alexander looks rather ridiculous in the sober and ugly Roman features, as we know them from his coins and from his best sculptured portrait in Copenhagen.[55] Pompey's imitation of Alexander is, however, characteristic for the fact that the Roman conquerors were conquered by the conquered Greeks and adopted all their cultural achievements, adapting them to the Roman character and needs.

Thus, now being masters of all former Greek lands, the Romans continued to erect statues of Alexander in their cities as in the Hellenistic cities. The quaestors of Alexander's homeland Macedonia, Aesillas (93–92) and Quintus Brutius Sura (92–88), substituted for the head of Herakles an idealized head of Alexander characterized by thick, long, and exaggeratedly curled hair, which stands up on the forehead and cascades down over the ears and the side and the nape of the neck (fig. 67).[56]

The sculptured heads in this and the following period tend toward the colossal in size, with enhancement of the features and of the emotional expression. A good example from the East is the limestone head found by the Swedish Cyprus Expedition in Soli (figs. 68–69) [57] and from the

[54] For the coins of Mithridates see Wroth, W., *British Museum catalogue of coins, Pontus*, pls. VIII–IX. Seltman, Ch., *Greek coins*, 237–238. Hill, G. F., *Historical Greek coins*, 160–163. Newell, E. T., *Royal Greek portrait coins*, 40–42, figs. 3–4. For the portrait in the Louvre: Winter, F., *Arch. Jahrb.* **9**: 245–250, pl. 8, 1894. For the group with Mithridates as Herakles liberating Prometheus, see Krahmer, G., in *Arch. Jahrb.* **40**: 183–205, figs. 1–2, 11–12, 1925.

[55] For the coins of Pompey see Bernoulli, J. J., *Römische Ikonographie* I: 107–111, Münztafel II, nos. 36–48, 51–52. Vessberg, Olof, *Studien zur Kunstgeschichte der römischen Republik*, 135–137, pl. V. For the head in Copenhagen see *Katalog*, 404–405, no. 597, 1940. Hekler, A., *Bildniskunst*, pl. 155a. Delbrück, R., *Porträts*, XLIII, fig. 17 and XLVI, pl. 32. Arndt, P., *Porträts*, pls. 523–524. Schweitzer, B., *Die Bildniskunst der römischen Republik*, 86–88, figs. 117, 124–125, 1948.

[56] Schreiber, Th., *op. cit.*, 179–180, pl. XIII, 18–19. Head, Barclay V., ed. R. S. Poole, *British Mus. cat. of coins, Macedonia*, 19–20. Hill, G. F., *Historical Greek coins*, 158–160, pl. XII, 92–93. Head, Barclay V., *Historia Numorum*, 240–241, fig. 153. Gaebler, H., *Die antiken Münzen Nordgriechenlands* III, Makedonia und Paionia, Vol. III, 1: 69–73, pl. III, nos. 1–5; Vol. III, 2: 9, pl. III, 13–15. Ujfalvy, C. de, *op. cit.*, 157, fig. 70. Gebauer, K., *op. cit.*, 22–23. Our fig. 67 is a coin in the Newell Collection, American Numismatic Society of New York. I owe the photograph to the kindness of Agnes B. Brett.

[57] Gjerstadt, E., in *The Swedish Cyprus Expedition 1927–1931* III: 506; 526–527, no. 520, pl. CLXIII, 1–2, 1937. Westholm, A., The Temples of Soli, in *The Swedish Cyprus Expedition* III: 132, no. 520, pl. XIV, 1936.

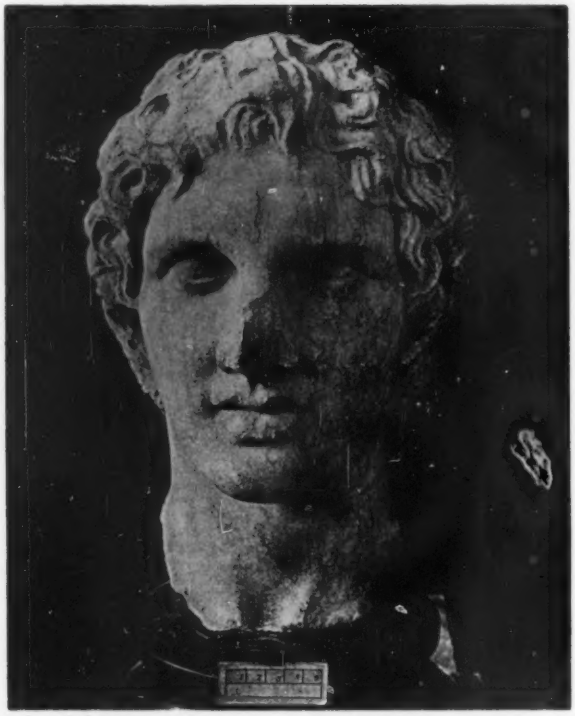
FIG. 1. Philip II. Medallion from Tarsos.

FIG. 2. Olympias. Medallion from Abukir.

FIG. 3. Alexander and Olympias. Cameo in Leningrad.

FIG. 4. Alexander and Olympias. Cameo in Vienna.

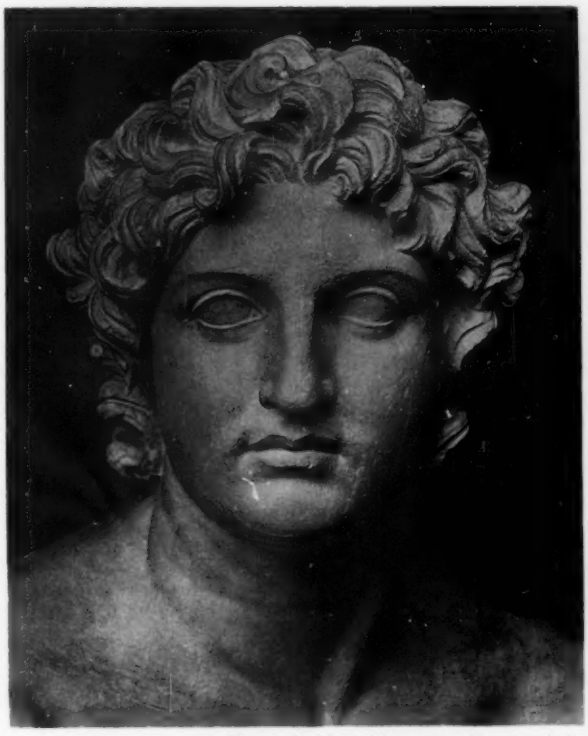
THE PARENTS OF ALEXANDER

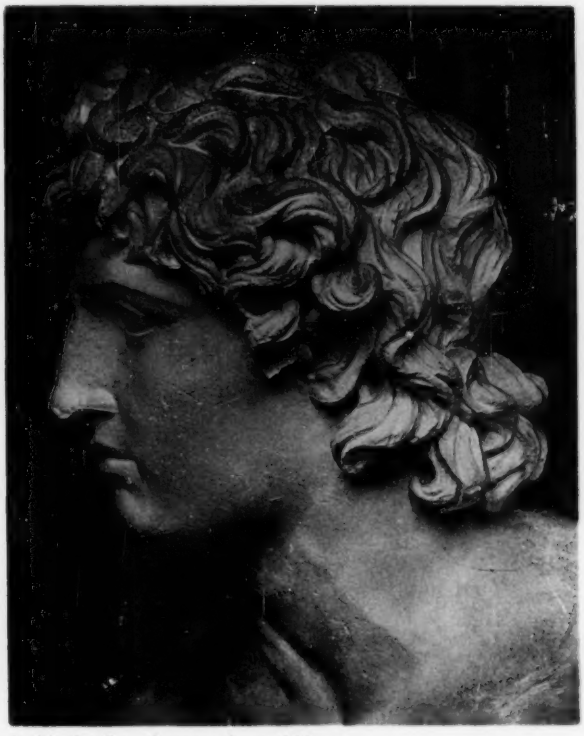


FIGS. 5–6. Head. Athens.

FIGS. 7–8. Head. Musée Guimet, Paris.

ALEXANDER AS CROWN PRINCE





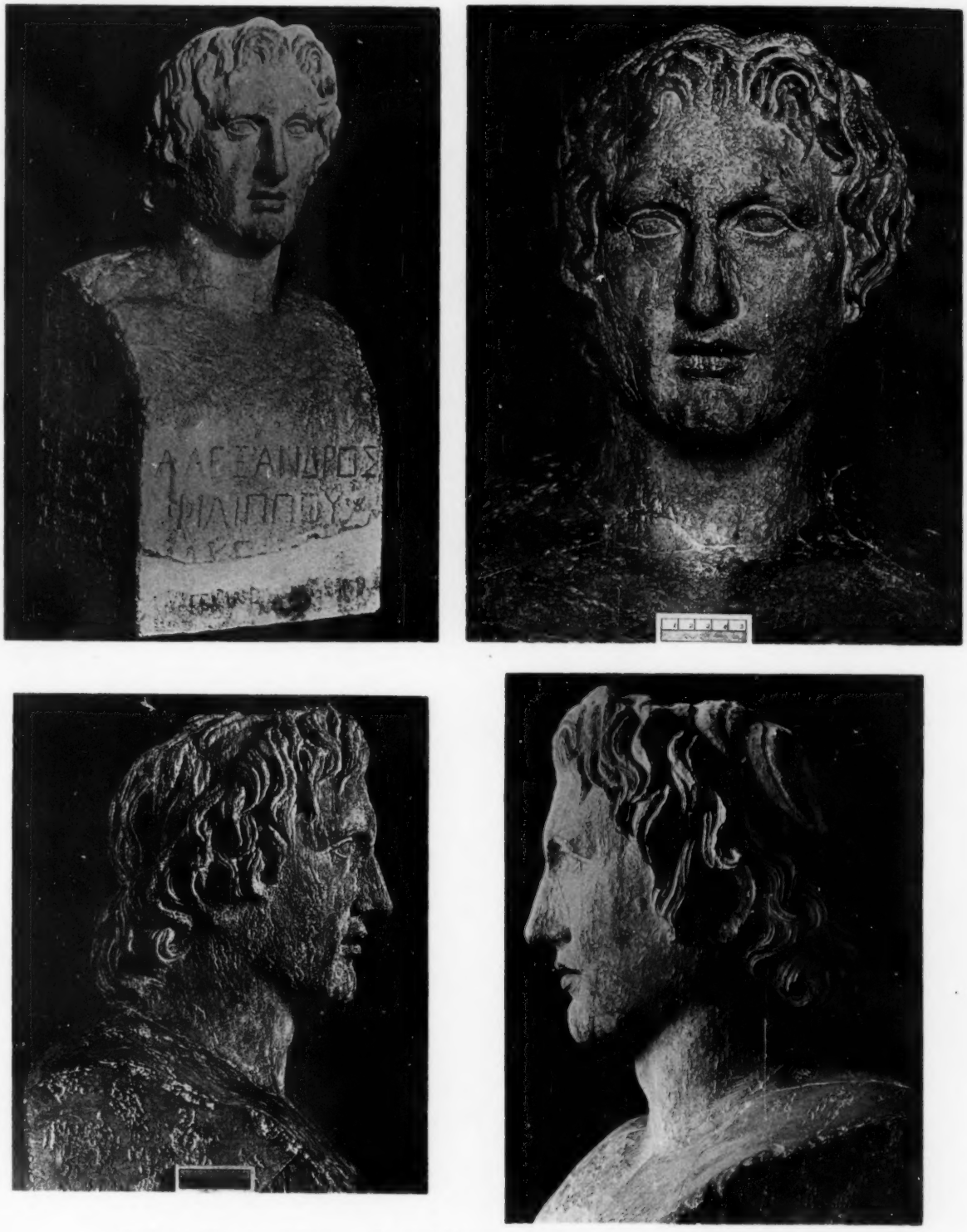
FIGS. 9–11. Alexander Rondanini, probably by Leochares, about 338 B.C.

FIG. 12. Coin issued by Lysimachus, Hellenistic adaptation of figure 9.

THE YOUNG GENERAL OF PHILIP

FIG. 13. Azara Herm. Copy of Alexander with the Lance by Lysippus. Louvre.

THE CONQUEROR OF GREECE AND PERSIA



FIGS. 14–17. Azara Herm. Copy of Alexander with the Lance by Lysippus. Louvre.

THE CONQUEROR OF GREECE AND PERSIA

FIG. 18. Copy of Alexander with the Lance by Lysippus. Bronze. Louvre.

FIG. 19. Hellenistic adaptation of figure 18. Grado.

FIG. 20. With Aegis. Alexandrian bronze. Cairo.

FIG. 21. With Aegis. Alexandrian statuette. Louvre.

FIG. 22. Riding on Bucephalus. Bronze. Probably copy from a group by Lysippus. Naples.

THE BATTLE AT THE RIVER GRANICUS, 334 B.C.

FIGS. 23–24. Riding on Bucephalus. Bronze. Probably copy from a group by Lysippus. Naples.

FIG. 25. Head Dressel. Copy of a portrait by Lysippus. Dresden.

FIG. 26. With thunderbolt, on Neison gem. Probably inspired by a painting of Apelles. Leningrad.

PORTRAITS BY HIS COURT ARTISTS

FIG. 27. Alexander riding on Bucephalus.

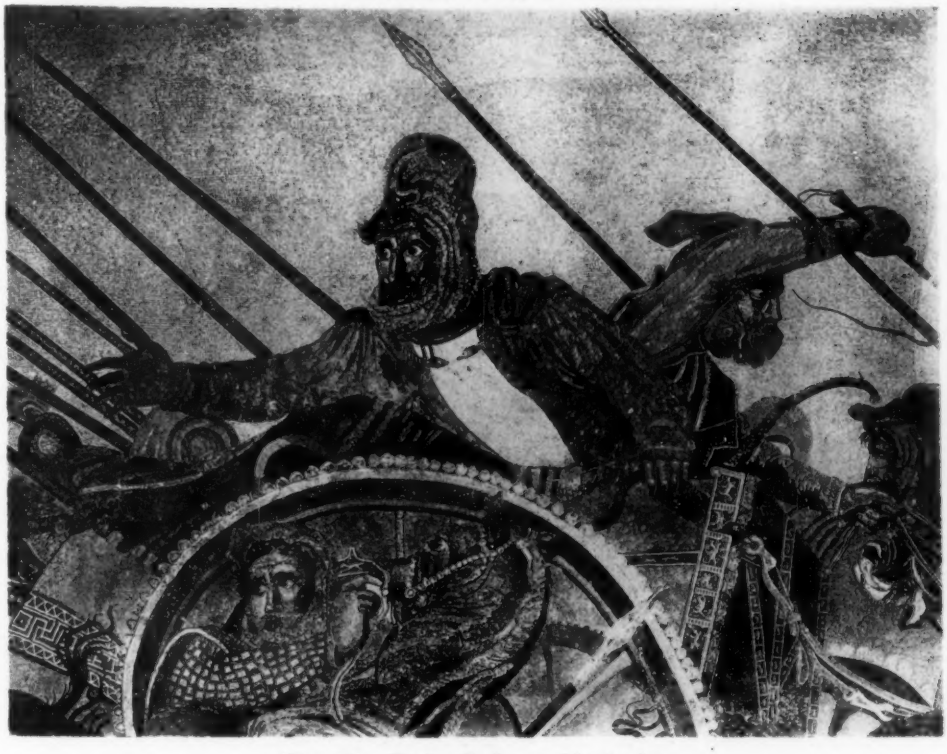


FIG. 28. Darius fleeing on his chariot.

DETAILS FROM THE ALEXANDER MOSAIC. BATTLE OF ISSUS, 333 B.C. NAPLES.
Copy of the painting of Philoxenus of Eretria, related to style of Apelles.

FIGS. 29–30. In battle.

FIG. 31. In lion hunt.

FIG. 32. Coin minted in Sidon.

DETAILS FROM ALEXANDER SARCOPHAGUS. ISTANBUL.
Made for Abdalonymus of Sidon in the time of the Successors.

FIG. 33. Coin minted in Babylon.
Lifetime, about 324 B.C.

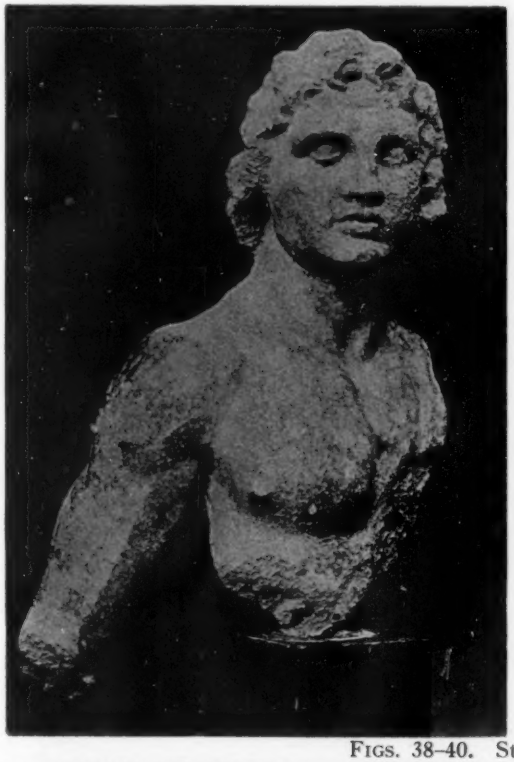
FIGS. 34–35. Coins issued by Ptolemy I of Egypt since 318 B.C.

EARLIEST COIN PORTRAITS

FIG. 36. Coin issued by Ptolemy I as Satrap of Egypt (323–305) about 318 B.C.

FIG. 37. Coin issued by Lysimachus as King of Thracia (306–281).

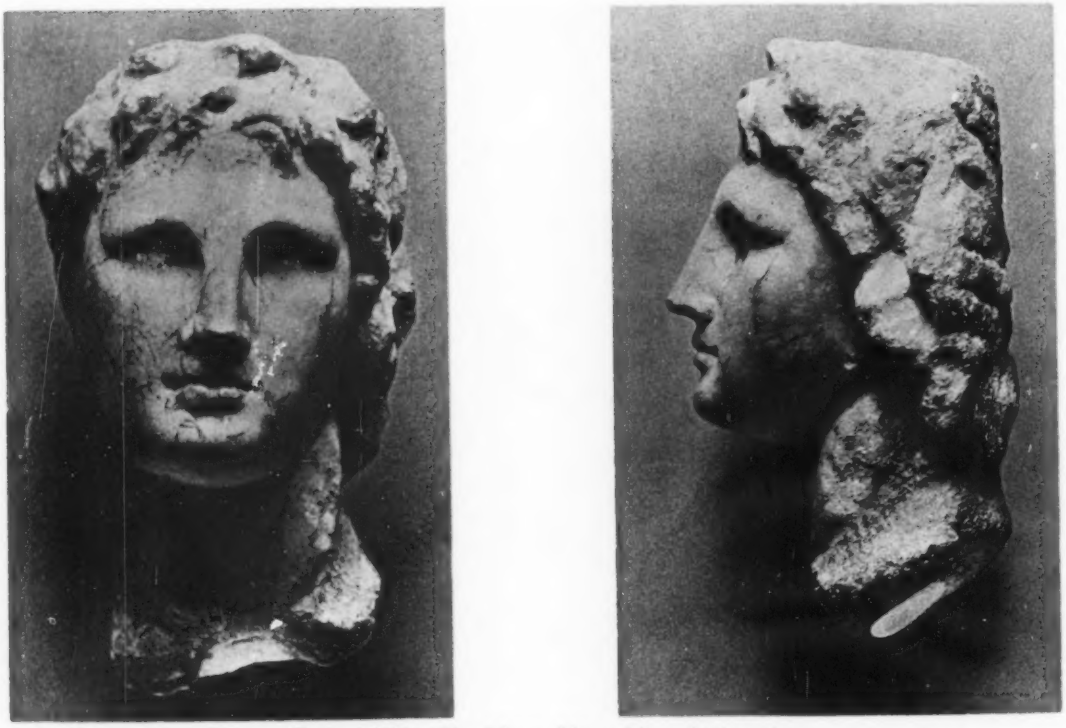
PORTRAITS ON COINS OF HIS SUCCESSORS (DIADOCHS)



FIGS. 38–40. Statuette from Priene.

FIG. 41. Coin issued by Lysimachus at Magnesia on the Meander.

PORTRAITS ABOUT 300 B.C.



FIGS. 42–44. Head from Alexandria. Stuttgart.

FIG. 45. Coin issued by Lysimachus at Lampsacus in Mysia, 291/0 B.C.

PORTRAITS IN THE ALEXANDRIAN STYLE. THIRD CENTURY B.C.

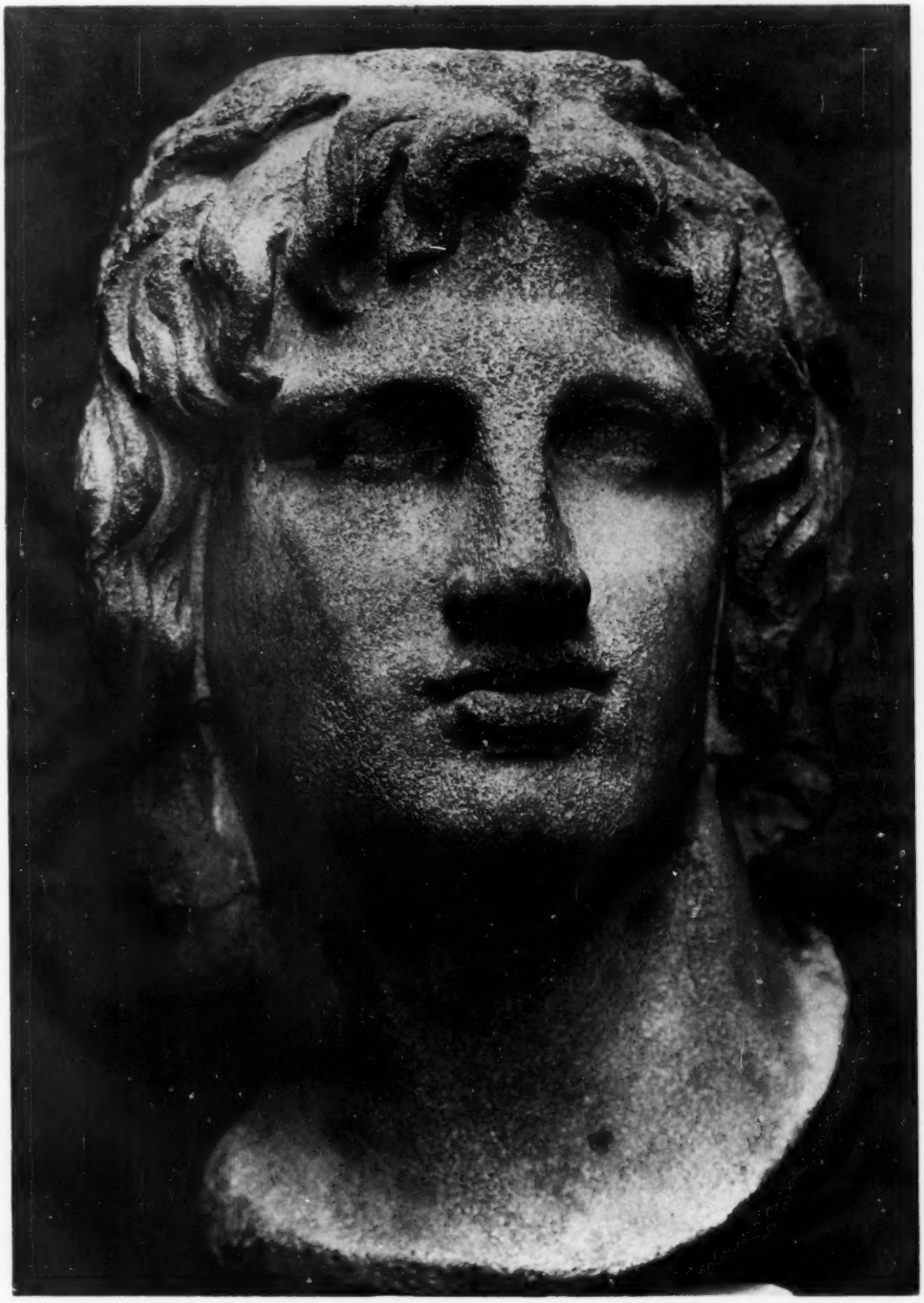


FIG. 46. Head from Alexandria. British Museum.

PORTRAIT IN THE ALEXANDRIAN STYLE

FIGS. 47-48. Head from Alexandria. Cleveland, Ohio.

PORTRAIT IN THE ALEXANDRIAN STYLE

FIGS. 49–50. Head, found in Cos. Istanbul.

FIGS. 51–52. The same head restored with helmet.

IDEALIZED PORTRAIT

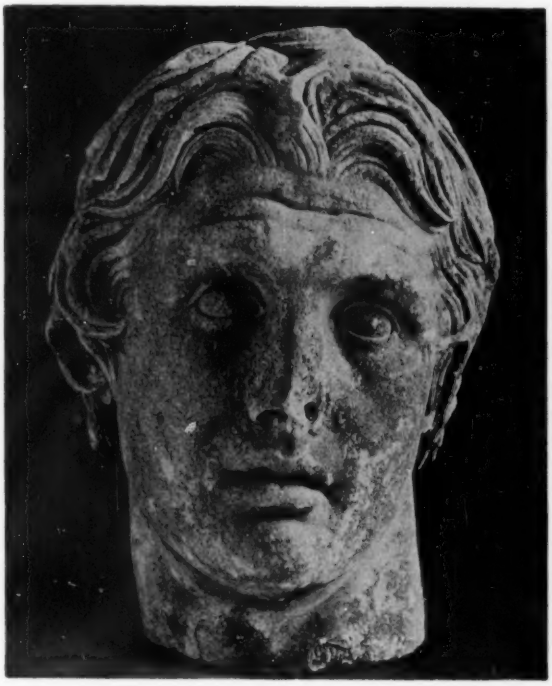
FIG. 53. Alexander-Herakles on coin. About 250–200 B.C. Boston.

FIG. 54. Same. Giessen.

FIG. 55. Same in three-quarter view, from Cos. About 200 B.C. Berlin.

FIG. 56. Same on gold ring. Metropolitan Museum, New York.

PORTRAITS OF ABOUT 250–200 B.C.



FIGS. 57–58. Head from Pergamon.

FIG. 59. Medallion from Abukir, based on type figure 57.

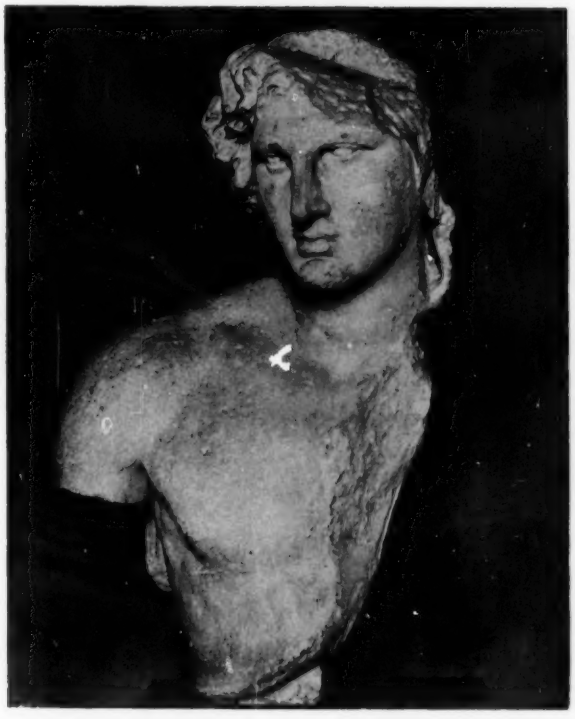


FIG. 60. Fragment of a statue from Delos. Louvre.

ASIATIC BAROQUE PORTRAITS

FIG. 61. Coin from Priene, about 200–190 B.C.

FIG. 62. Coin from Miletus, about 190–170 B.C.

FIG. 63. Coin from Bactria, issued by Agathocles, about 170 or 168/7 B.C.

FIG. 64. Coin from Mesembria in Thrace, about 150 B.C.

PORTRAITS ON COINS OF ABOUT 200–150 B.C.

FIGS. 65–66. Statue from Magnesia. Istanbul.

FIG. 67. Coin struck by Aesillas in Macedonia 93/2 B.C.

LATE HELLENISTIC PORTRAITS OF ALEXANDER

FIGS. 68–69. Head. Soli, Cyprus.

FIGS. 70–71. Head. Capitoline Museum, Rome.

PORTRAITS OF THE FIRST CENTURY B.C.

FIG. 72. Bronze statuette. Flavian period (A.D. 69–96). Bibliothèque Nationale, Paris.

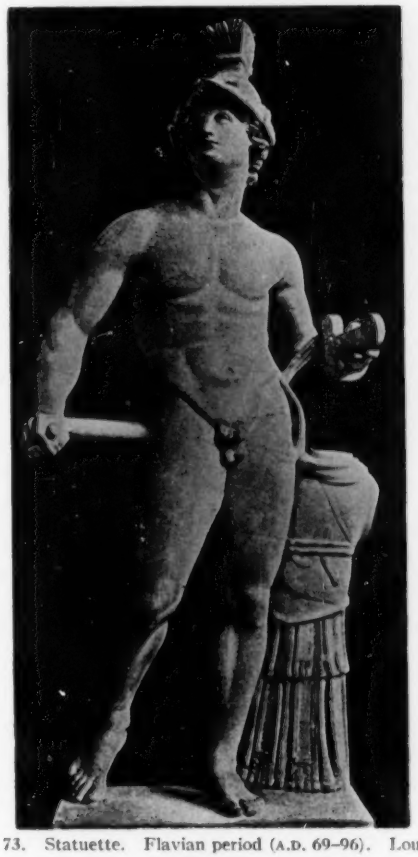


FIG. 73. Statuette. Flavian period (A.D. 69–96). Louvre.

FIGS. 74–75. Porphyry head. Period of Hadrian (A.D. 117–138). Louvre.

PORTRAITS OF THE ROMAN PERIOD

FIGS. 76–77. Head. Boston.

FIGS. 78–79. Statue. Cyrene.

PORTRAITS FROM THE PERIOD OF THE ANTONINES TO CARACALLA (A.D. 138–217)

FIGS. 80–81. Head. Barracco Collection, Rome.
PORTRAIT OF THE THIRD CENTURY A.D.

FIGS. 82–86. Macedonian coins, issued A.D. 231–249.

PORTRAITS OF THE FIRST HALF OF THE THIRD CENTURY A.D.

FIGS. 87–88. Medallions from Tarsus, issued A.D. 242–245.

FIG. 89. Coin of Apollonia Mordiaeum in Pisidia, issued by Elagabalus (A.D. 218–222).

FIGS. 90–92. Contorniates, fourth to fifth century A.D.

West the marble head in the Capitoline Museum in Rome (figs. 70–71).[58] Both show the anastole and the lion's mane—that is, the hair raised over the forehead, then framing the face and falling down in full strands—and the high forehead, large eyes, broad nose, slightly opened mouth, energetic chin, and long cheeks. The neck is strong and, in the well-preserved Capitoline head, bent toward the right shoulder, while the head is bent to the left and noticeably lifted. Thus, in spite of the fact that the usual vigor of the personal expression is replaced by a more general and almost cold and sophisticated spirit, there is no doubt that this is a portrait of Alexander. The contrasted movements of neck and head are exaggerated. The hair forms a thick and irregular frame around the head. Such luxuriant growth of hair was considered to be the seat of strength and power. The features are large and simple, the eyebrows prominent, the eyes deep-set, the lips full and short. The head has been interpreted as Alexander Helios or as the sun-god assimilated to the type of Alexander. The fact that the quality of the head in Rome is better than that of the provincial and rather clumsy one from Soli is in accord with the fact that the best Greek artists were now working in the Roman capital.

For the Romans as for the later Greeks Alexander was a man of superhuman achievements, who like Herakles had become divine on the basis of his own illustrious deeds.

VIII. CONCEPTIONS DURING THE ROMAN EMPIRE (FIRST TO THIRD CENTURY A.D.)

Since the second century B.C. the Romans had absorbed by and by all the Greek states which once had been under the sway of Alexander. T. Quinctius Flamininus had proclaimed the Greek mainland states free and independent from Macedonia in 197 B.C., but in reality they were subordinated to Roman governors and had to pay tribute to Rome. Egypt and Asia had to obey Roman orders since the same period. Then one state after the other became part of a Roman Empire. In 168 Macedonia became dependent on Rome and in 146 a Roman province. The kingdom of Pergamon was bequeathed to the Romans in 133, and Syria and all Asia followed. Finally Egypt, dependent on the Romans since the second century, was made a Roman province in 30 B.C. after the death of Cleopatra, the last great Hellenistic ruler. The Romans adopted Alexander's idea that harmony, peace and brotherhood ought to unite all mankind without regard to their race. The Romans by and by gave Roman citizenship to all the different people who lived in their Empire. Thus the brotherhood of men which Alexander had wished came true in the Roman Empire. The Romans, therefore, considered themselves, with good reason, heirs to the empire of Alexander. They gave him the title Alexander Magnus. Augustus, called a friend of Alexander by Strabo (XIII, 594), put Alexander's head on his signet ring (Sueton, *Augustus* 50; see our fig. 56). The artists of the imperial period continued to create portraits of the great conqueror whose life became more and more a legend.

Roman art during the Empire was based mostly on Greek art, but it was not a direct continuation of the late Hellenistic style. Periods of Classicism, when Phidias and Praxiteles were the models, as in the time of Augustus, of the Claudians, and of Hadrian, alternated with periods when Hellenistic emotionalism was the ideal, as under the Flavians and the Antonines. A product of the classicistic tendency was the flourishing of schools of copyists, the best being those of the two first centuries, before and after Christ. To this period belong the good copies of the contemporary portraits of Alexander (figs. 5–26).

It was probably during the Flavian period (A.D. 69–96) that a new conception of Alexander based on the irrational and romantic Hellenistic ideal led to such creations as the colossal heads of Alexander in Chatsworth,[59] the face of which is nine inches long, and from Tarsus in Copenhagen,[60] with the remains of an Ammon's horn. They have a crown of curly hair which frames the face and falls in heavy masses onto the nape of the neck. Over the forehead it stands up in the

[58] Arndt, P., *op. cit.*, pls. 186–187. Hekler, A., *Bildniskunst*, pl. 62a. Ujfalvy, C. de, *op. cit.*, pl. III. Schreiber, Th., *op. cit.*, 68–78, pl. V, K. Helbig, W., *Mon. ant. dei Lincei* VI: 73–88, pl. II, 1895. Bernoulli, J. J., *op. cit.*, 65–69, pl. VII; Stuart Jones, *Sculptures of the Museo Capitolino*, 341–342, Stanza del Gladiatore, no. 3, pl. 85. Laurenzi, L., *op. cit.*, 105–106, pl. XV, no. 41. Restored: pieces of hair on the back of the neck; tip of nose; bust.

[59] Furtwängler, A., in *Jour. Hell. Stud.* **21**: 212–214, pls. IX–X, 1901. Ujfalvy, C. de, *op. cit.*, 174–175, figs. 78–80. Schreiber, Th., *op. cit.*, 59–64, pl. IV, G. Bernoulli, J. J., *op. cit.*, 52, fig. 11. Gebauer, K., *op. cit.*, 75, K 72.

[60] Poulsen, F., *Billedtavler*, pl. 33, no. 445. *Idem*, *Katalog*, 312, no. 445. Poulsen dates it in the second century between Hadrian and the Antonines.

anastole. Some bronze statuettes have a similar head but are too small to be identifiable.[61] The statues of which the colossal heads were a part must have been of similar rather affected attitude. They represented the deified, not the human, Alexander.

The same is true of two statuettes in Paris, which may belong to this period, one standing, in the Louvre, and one seated, in the Cabinet des Médailles, of Alexander with helmet and weapons. The standing figure in marble, which was found in Gabii (fig. 73),[62] is poor in workmanship and in a bad state of preservation, but it has the same exaggerated movement of the head with a still stronger upward turn. The corselet beside the left leg indicates that the statuette is that of a general. The right hand probably held the sword, and the left hand only the scabbard. The strong swing of the hip is patterned after Praxitelean statues. The seated figure in bronze from Reims, in the Cabinet des Médailles of the Bibliothèque Nationale (fig. 72),[63] has a still more heightened sentimentality. The lance in the right hand and the sword in the left are probably correct restorations. The broad body is draped with a mantle in the grand manner. The locks are long, full, and irregular as in the Capitoline head (figs. 70–71). The idea of Alexander as godlike, but at the same time a ruler of the world who trusted his own weapons and was thus on a level with Zeus, is behind these Roman creations, and there was a statue of Alexander as Zeus in Olympia (Pausanias, V, 25, 1).

The cool classicism of the Hadrianic age (A.D. 117–138) toned down this false emotional approach in art. A good example of this trend is the over-life-size porphyry head in Paris (figs. 74–75).[64] The hair falls in more regular fashion; the movement, though strong, particularly in the neck, is more natural and the modeling of the features shows a tendency toward artificial construction of the single parts of the face. Thus the eyebrows are broken in sharp angles, the lips are separated from their surroundings by exaggeratedly deep curved lines. The sharp divisional lines are then glossed over with high polish. Alexander has now become the object of arbitrary interpretation, artistically as well as ethically.

It is therefore not to be wondered at that the colossal statue found in the Roman Baths at Cyrene (figs. 78–79),[65] has been interpreted as Dioscurus, as Helios, and as Alexander. It seems likely that the statue is one of Alexander and that the horse beside him is an allusion to his steed Bucephalus. The object in his left hand, of which only the lower part is preserved, is probably the lance. Behind it hangs the chlamys, attached to the left shoulder, where it is collected by a large round fibula. The hair is heavier and more wildly arranged than in any of the older portraits. The excessive use of the drill in separating the single strands dates the figure in the early Antonine period. To the same period belongs the sharp contrast between the dark hair with its strong play of light and shade and the highly polished surface of the face. A similar contrast is found in a probably contemporary over-life-sized statue in Wilton House,[66] in a head perhaps already of the early third century in the Barracco Collection (figs. 80–81),[67] and a head in Madrid.[68]

[61] Schreiber, Th., *op. cit.*, 124–128, pl. XI, R, 1. Ujfalvy, C. de, *op. cit.*, 121, fig. 35. There are many other bronze statuettes supposedly of Alexander, as in Schreiber, Th., *op. cit.*, 71, 91–93, 124–129, pls. VI, 2; VIII, 2; XI, 2; 285, fig. 35. Wulff, O., *Alexander mit der Lanze, Bronzestatuette der Sammlung Nelidow*, 1898; and the wooden statuette in the Louvre, in Gebauer, K., *op. cit.*, 37–38, K 7, pl. 5—all of which seem to me too sketchy to be of any help in the study of the portrait of Alexander and have, therefore, been left out of this paper.

[62] Bernoulli, J. J., *op. cit.*, 83–84, fig. 25. Schreiber, Th., *op. cit.*, 111–113, pl. VII, N. Gebauer, K., *op. cit.*, 79–80, K 82. Suhr, E. G., *op. cit.*, 108–109, fig. 18. Restored: part of crest, edge of helmet, part of neck, strip in left shoulder, left hand, right arm, right lower leg, part of left lower leg, left foot, upper corner and lowest portion of corselet.

[63] Babelon, E., and A. Blanchet, *Catalogue des Bronzes de la Bibliothèque nationale*, 356, no. 824. Ujfalvy, C. de, *op. cit.*, pl. V. Schreiber, Th., *op. cit.*, 113–114, pl. VIII, O. Bernoulli, J. J., *op. cit.*, 115–117, fig. 39. Babelon, J., *Choix des Bronzes des Collections de Janzé et Opperman*, 17, pl. III, 1929. The throne is modern but the base is ancient.

[64] Delbrück, R., *Antike Porphyrwerke*, 60–62, fig. 12, pl. 15. Gebauer, K., *op. cit.*, 79, K 81.

[65] Maviglia, Ada, in *Revue Arch.* sér. 5, **3**: 169–183, 1916. Ghislanzoni, E., *Notiziario archeologico* II: 105–122, figs. 47–48, 51, 54, pls. V–VI, 1916. Bagnani, G., in *Jour. Hell. Studies* **41**: 237–238, pl. XVII, 1, 1921. Hill, Dorothy, in *Art. Bull.*, 157, note 2, 1942. Laurenzi, L., *op. cit.*, 132, pl. XLI, no. 101.

[66] Poulsen, F., *Greek and Roman portraits in English country houses*, 37–38, fig. 9.

[67] Helbig, W., in *Mon. ant. dei Lincei* **6**: pl. 3, 1895. *Idem, La Collection Barracco*, 43–45, 62, pls. 57 and 57a. Arndt, P., *op. cit.*, nos. 477–478. Schreiber, Th., *op. cit.*, 67–71, pl. V, J. Suhr, E. G., *op. cit.*, 92–93, fig. 11. Bernoulli, J. J., *op. cit.*, 77–79, figs. 19–20. Laurenzi, L., *op. cit.*, 106, pl. XVI, no. 42. H.0.28m. No restorations have been made.

[68] Arndt, P., *op. cit.*, pls. 483–484. Bernoulli, J. J., 84–86, fig. 26.

The best and perhaps one of the latest sculptured Alexander portraits is the grandiose head from Ptolemais in the Boston Museum (figs. 76–77),[69] which seems to be of the period of Caracalla (A.D. 211–217). Caracalla, like formerly Mithridates and Pompey, not only imitated the appearance of Alexander in his own attitude, dress, and portraits, but also ordered many pictures and statues of Alexander to be set up everywhere in Thrace; and he filled Rome with statues and pictures of Alexander in the Capitoline as well as in other sanctuaries (Herodianus IV, *Antoninus Caracalla* 8, 1). The face of the Boston head is almost ten inches in length. The forms of the features are still those of Alexander idealized to youthful beauty. The expression is that prevailing in a later age when Alexander has become no longer human, but a hero like Achilles or Herakles, or transfigured to a god like Apollo or Zeus. The oblique neck is combined with an upturned movement and an emotional look up to heaven.

In the later period of Alexander Severus, beginning in 231 of our era, continuing under Gordian III (242–243), and ending under Philippus II Arabs in 249, coins with portraits of Alexander were minted in Beroia, the capital of the Macedonian League.[70] They show at least five different types.[71] Alexander in one group appears with thick hair fluttering almost horizontally and with the anastole (fig. 82).[72] In another group he has the same anastole, but the hair is encircled by a diadem and hangs almost vertically. Often an Ammon's horn is added (fig. 84).[73] A third type has the head covered by a lion's skin (fig. 85).[74] Diadem, anastole, corselet, and shield are found in another group (fig. 86),[75] and a helmet covers the head in still another type (fig. 83).[76]

Whereas the coins with the Ammon's horn and the lion's skin may have been influenced by the older coins of Lysimachos and of Macedonia (see figs. 12, 37, 41, 67), they and particularly the three other types as well seem rather to have been influenced by statues which were in existence then, such as the statue in Cyrene (figs. 78–79), and those from which came the colossal heads in the Capitoline Museum (figs. 70–71), in the Barracco Museum (figs. 80–81), the one found at Ptolemais in Boston (figs. 76–77), and the one found at Tarsus in Copenhagen. The reverse of the Macedonian coins shows, in addition to Alexander—fighting, hunting, or taming Bucephalus—and his mother Olympias (see above), a temple and a table with prizes.[77] These allude to the festivals in honor of the Roman emperors and the deified Alexander, for which these coins or contorniates were issued. There certainly must have been erected in this and other temples cult statues not only of the emperors but also of Alexander. There were, moreover, portraits of Alexander set up in private chapels. Thus Alexander Severus had one in his Lararium together with the best deified emperors (Aelius Lampridius, *Alexander Severus*, XXXI, 5).

From the coins and the late Roman colossal statues we can learn how these portrait statues of Alexander may have looked. They had the

[69] Helbig, W., in *Mon. ant. dei Lincei* **6**: 75–88, pl. I, 1895. Bernoulli, J. J., *op. cit.*, 70–74, figs. 16–17. Arndt, P., *op. cit.*, pls. 481–482. Ujfalvy, C. de, *op. cit.*, pl. IV. L'Orange, H. P., *Apotheosis in ancient portraiture*, 34–37, fig. 17. He wrongly considers the Boston head a replica of the Capitoline head, figs. 70–71. Caskey, L. D., has not included it in his *Cat. of Greek and Roman Sculpture, Museum of Fine Arts, Boston*, 1925. Bieber, M., in *Amer. Jour. Arch.* **49**: 425, figs. 1–2, 1945, has proved the authenticity of the Boston head. H.0.48m; length of face 0.243m. No restorations have been made.

[70] Gaebler, H., in *Ztschr. für Numismatik* **24**: 316–338, pls. VI–VII, 1904; **25**: 1–38, pls. I–III, 1906. *Idem, Die antiken Münzen Nordgriechenlands* III, *Die antiken Münzen von Makedonia und Paionia* III, 1: 14–25, 94–196, pl. IV, 11–19; III, **2**: 12–18, 47–48, pl. IV, 19–23, pl. XI, 25–28. Schreiber, Th., *op. cit.*, 180–184, pl. XIII, 13–14, 20–23.

[71] Gaebler, H., in *Ztschr. für Numismatik* **25**: 8–12, 1906; *idem, Münzen von Makedonia* III, 1: 15, adds five variants. *Cp.* Gebauer, K., *op. cit.*, 22–23.

[72] Fig. 82 is taken from *Ztschr. für Numismatik* **25**: pl. II, 28, 1906. Other examples, *ibid.*, **24**: pl. VI, 6, 10–11, pl. VII, 21–22, 26, 30, 32, 1904; **25**: pl. I, 11, pl. II, 27, 30, 1906. *Münzen von Makedonia* III, 1: pl. IV, 12–13; III, 2: pl. IV, 20. Bieber, M., *op. cit.*, 428–429, fig. 3.

[73] Fig. 84 is taken from *Ztschr. für Numismatik* **25**: pl. II, 35, 1906. Other examples, *ibid.*, pl. I, 5, 6, 10, 12–14, 16; pl. II, 23, 33, 34; pl. III, 39, 40, 43. *Münzen von Makedonia* III, 1: pl. IV, 11; III, 2: pl. IV, 19. Bieber, M., *op. cit.*, fig. 4.

[74] Fig. 85 is taken from *Ztschr. für Numismatik* **25**: pl. III, 38, 1906. Other examples, *ibid.*, **24**: pl. VI, 9; pl. VII, 25, 29, 1906; **25**: pl. I, 4; pl. II, 26, 36; pl. III, 47, 1906. *Münzen von Makedonia* III, 1: pl. IV, 14; III, 2: pl. XI, 25. Bieber, M., *op. cit.*, fig. 5.

[75] Fig. 86 is taken from *Ztschr. für Numismatik* **25**: pl. III, 55, 1906. Other examples, *ibid.*, pl. III, 45, 48. *Münzen von Makedonia* III, 1: pl. IV, 18–19; III, 2: pl. IV, 23. Bieber, M., *op. cit.*, fig. 6.

[76] Fig. 83 is taken from Gaebler, H., *Münzen von Makedonia* III, 2: pl. XI, 28. Other examples, *ibid.*, III, 1: pl. IV, 15–17; III, 2: pl. IV, 21; pl. XI, 27. *Ztschr. für Numismatik* **25**: pl. I, 17; pl. III, 56–57, 1906.

[77] Gaebler, H., in *Ztschr. für Numismatik* **25**: 27–29, 1906. For the temples see pl. I, 12; pl. II, 31. Temple and prize table, pl. III, 41, the reverse of our fig. 85.

strong expressiveness which is a characteristic of late Roman style. Thick and irregular strands of hair, expressing power, a noticeable lifting of the head, expressing transfiguration, deepset eyes with a look upturned to heaven, giving an emotional expression.[78] This Roman conception is based on the irrational and romantic Hellenistic conception of Alexander, but it adds exaggerated movement and heightened emotion.

The celebrated golden medallions found at Abukir in Egypt, in the same country as the Boston head (figs. 76–77), and at Tarsus in Cilicia, found in the same place as the head in Copenhagen, are of the same period as the late Macedonian coins (figs. 82–86), as testified by the portraits of Caracalla (211–217) and Alexander Severus (222–235) on some of them.[79] They have been dated in the year 242–243 and explained as prize medallions for victories in the Olympian festival celebrated at Beroia in the presence of Gordian III in that year.[80] The many portraits of Alexander and scenes related to his deeds prove that the contests were given in honor of the deified Alexander. I believe, therefore, that these medallions, like the one representing Philip (fig. 1), are based mostly on statues. The medallion from Abukir in front view (fig. 59) reminds one of the head found in Pergamon (figs. 57–58); but the fluttering strands of the hair and ends of the diadem, the exaggerated emotional expression, and the over-crowding of the corselet and shield with symbolic representations betray Roman taste. The medallion from Tarsus with the lion's skin (fig. 87) is a very free adaptation of the older coins, but the horizontally fluttering hair of the medallion with diadem (fig. 88), with its very schematic arrangement, has its nearest parallel in the contemporary coin of Beroia (fig. 82).

Roman portraits of Alexander are mentioned for a still later period. Trebellius Pollio (*Triginta Tyranni*, XIV, 14, 3–6) says that the family of the Marciani, who were adversaries of Gallienus (260–268) in the period of the thirty tyrants, still in the writer's own days, that is the time of Diocletian (284–305), decorated not only their ringstones, but also their silver plates, the embroideries of their tunics, cloaks and fillets as well as ornaments of every kind with portraits of Alexander. "It is said, that those who wear the likeness of Alexander carved in either gold or silver are aided in all that they do" (Trebellius Pollio, *op. cit.*, XIV, 6). At the end of the fourth century St. John Chrysostomos blamed the people of Antioch, because they wore bronze coins of Alexander the Macedon around their necks and ankles. We have, indeed, named portraits of Alexander until the end of antiquity.

To the third century belong the bronze coins of Elagabalus (218–222) issued at Apollonia Mordiaeum in Pisidia (fig. 89) inscribed "Alexander founder of Appollonia";[81] and to the fourth and perhaps fifth centuries, the contorniates (figs. 90–92) from the Newell Collection in the American Numismatic Society.[82] On the reverse of figure 90 and on the obverse of figure 91 is inscribed ALEXANDER MAGNUS MACEDON. On

[78] For the transfigured Alexander see L'Orange, H. P., *Apotheosis in Ancient Portraiture*, 28–38, figs. 12–17, 1947.

[79] See for both groups: Neuffer, E., *op. cit.*, 18–20. Regling, K., *Die antiken Münzen*,[3] 149–150, Berlin, 1929. L'Orange, H. P., *op. cit.*, 20–21, 24, figs. 4–5. Illustrated together also by Svoronos, J. N., in *Journal int. d'archéol. Numism.* **10**: pls. VIII–XIV, 1907. For the medallions from Abukir see Dressel, H., *Fünf Goldmedaillons aus dem Funde von Abukir, Abh. preuss. Akad. d. Wiss.*, with pls. I–IV, 1906. Koester, E., Gold Medallions of Abukir, in *Burlington Mag.* **11**: 162–163, 1907. Gebauer, K., *op. cit.*, 23–25. Newell, E., in *Amer. Jour. Num.* **44**: 128–130, pls. 14–15, 1910. Doubts cast on the authenticity of these Abukir medallions by Dattari, G., *I Venti Medaglioni d'Abusir*, 1908, and others have been refuted by Dressel and others. See, particularly, Newell, E., *op. cit.*, 130: "It seems to be the present judgment of the best critics that the medallions of Abukir are genuine, and of the period claimed for them; as examples of Graeco-Roman art at its best, they constitute one of the most priceless classical treasures found in recent years." Newell later took a skeptical attitude. See Suhr, E. G., *op. cit.*, 184–186. See also Head, Barclay V., *Historia Numorum*, 241–242: "The authenticity of the twenty remarkable gold medallions discovered in Egypt (at Abukir?) in 1902 is still questioned by some leading numismatists, notwithstanding the powerful arguments in their favor advanced by Dressel (*op. cit.*), which no one has as yet been able to refute." *Cp.* also Bieber, M., in *Amer. Jour. Arch.* **49**: 429, 1945. For the medallions from Tarsus see Longpérier, A. de, in *Revue numismatique*, Nouv. Sér., **13**: 309–311, pls. X–XII, 1868. Movat, R., in *ibid.*, Sér. 4, **7**: 1, pls. I–II, 1903. Schreiber, Th., *op. cit.*, 189–193, pl. XIII, 16. Bernoulli, J. J., *op. cit.*, 29–30, fig. 3. Ujfalvy, Ch. de, *op. cit.*, 17, fig. 3, and 145, figs. 51 and 55. Gaebler, H., *Münzen von Makedonia* III, 1: 192–194.

[80] See Dressel, H., *op. cit.*, 52–63.

[81] Hill, C. F., *British Mus. cat. of coins, Lycia, Pamphylia*, 202, no. 1 and 204, nos. 9–10, pl. XXXIII, 1 and 5, 1897.

[82] I owe the photographs of these contorniates, which are in the Newell Collection of the American Numismatic Society, to Agnes B. Brett. See on contorniates: Alföldi, A., *Die Kontorniaten*, Budapest, 1943. Toynbee, Jocelyn M. C., *Roman Medallions*, Numismatic Studies No. **5**: 234–236 and 243, American Numismatic Society, New York, 1944.

figure 92 the inscription ALEKKANDER MAG testifies that this head with the lion scalp, the bulging forehead, the exceedingly big eyes expressing superior intelligence, the straight nose, the pouting and expressive mouth, with the radiated sun beside it, is meant to be the deified Alexander the Great. Thus the image and the greatness of Alexander were transmitted to the middle ages. Even Islam adopted him as one of its prophets.

CONCLUSION

From the number and diversity of these artistic expressions it can be seen how the unique personality of Alexander gave to the art of portraiture impulses which—after having been created in his own lifetime—carried on through the Hellenistic and Roman periods.

The liberal ideas of Alexander, giving equal rights to everybody, pushed into the background during the Hellenistic period, came to the fore again during the Roman period. Then, after having been neglected during the medieval, Renaissance, and Baroque periods, they came to life again during the American and the French revolutions in the eighteenth century. Since then they have been promoted by always larger groups of responsible personalities in different countries, such as the men in the revolutionary movements of France and Germany in 1848. While, however, these attempts on liberalism were suppressed in Europe—as they had been in the Hellenistic States—these ideas have taken deep roots in the United States of America. They are now promoted by the United Nations Commission on Human Rights.

HETEROPLOIDY IN TRITURUS TOROSUS

I. THE INCIDENCE OF SPONTANEOUS VARIATIONS IN A "NATURAL POPULATION"[1]

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INTRODUCTION

SYSTEMATIC studies of spontaneous variations of chromosome number within a given species have been carried on in this country for several years. Much of this work has been done by Fankhauser and his collaborators on salamander larvae, utilizing a tail-tip method (Fankhauser, 1938, 1941), comparable to the root-tip technique long used for plant material. The earlier literature in this field has been carefully reviewed by Fankhauser (1945). In general, the findings have indicated that the spontaneous incidence of polyploidy (especially triploidy) in the forms investigated is surprisingly high. Less frequent instances of spontaneous mosaicism and other heteroploid conditions are also reported.

Most of the larvae (*Triturus viridescens* and *Eurycea bislineata*) used in the studies of Fankhauser were derived from eggs laid in the laboratory by female salamanders which had been stimulated to ovulation by pituitary injection. Since *T. viridescens* eggs are small and deposited singly, it would be difficult to obtain enough young larvae from their natural habitat for a large-scale study of the incidence of heteroploidy in a natural population. This difficulty is obviated in the case of amphibians which normally lay their eggs in clusters or "clutches." An example of such a form is the California salamander, *Triturus torosus*. During the spring of 1948, a study of the incidence of heteroploidy and abnormal mitoses in larvae of this newt was therefore undertaken. To eliminate the possible effects of artificially-induced ovulation, egg clutches were collected in nature during the early part of the normal breeding season, when the eggs are deposited in shallow ponds. A few egg clutches from the later stream-breeding *T. torosus* were also used in this study. When collected, the eggs in the jelly masses were at various stages, ranging from early cleavage through neurulation to larvae almost ready to hatch. The further development of these embryos took place in the laboratory. Therefore, they do not constitute a true natural population, but one raised during part of their development under laboratory conditions.

Some of the data reported here were communicated earlier in a preliminary note (Costello and Henley, 1948).

We wish to express appreciation to Dr. Douglas Whitaker and to Dr. Victor C. Twitty for the use of laboratory facilities in the School of Biological Sciences at Stanford University during the winter and spring of 1948.

METHODS

The 582 *Triturus torosus* larvae used in this study were raised in the laboratory from clutches of eggs collected between January 11 and March 14 at various locales in the vicinity of Los Trancos, Ukiah, and Saratoga, California. Wherever possible, records were kept of water temperatures at the time of collection. The eggs were transported in a quantity of this water in thermos jugs without ice, and were distributed to large finger-bowls of Searsville Lake water (non-chlorinated) in the laboratory as soon as possible after collection. Shortly before the time of hatching, each clutch of eggs was isolated in a separate finger-bowl, so that the larvae (10–20) from a given clutch could be identified.

Since earlier work (Costello and Henley, 1947) has indicated the possibility that marked variations in temperature may result in mitotic abnormalities and in the production of chromosomal mosaics in *Triturus torosus* larvae, daily records were kept of the water temperatures in each finger-bowl. Seventy-nine of the 582 larvae were raised at temperatures of 23–26° C.; the remaining 503 were kept at 12–15° C. In general, embryos raised in the lower range of temperature were more viable.

Three groups of egg clutches, collected respectively at Saratoga, Los Trancos, and Ukiah were obtained from very cold water. Those from Los

[1] Aided by a grant from the American Philosophical Society.

Trancos appeared especially abnormal when collected, and gave the impression that they might previously have been frozen. The mortality rate was high in these eggs, as compared with other collections made at the same pond on a warm day. All 213 embryos derived from these Los Trancos, Saratoga and Ukiah clutches were raised at temperatures of 12–15°. One hundred thirty-two larvae were raised from egg clutches laid in the laboratory tanks by adult Los Trancos salamanders, and therefore were kept at a relatively constant temperature from the time of laying.

When the larvae reached a stage at which yolk resorption was complete (considerably beyond Twitty Stage 42; approximately equivalent to Harrison Stage 47) and feeding was about to

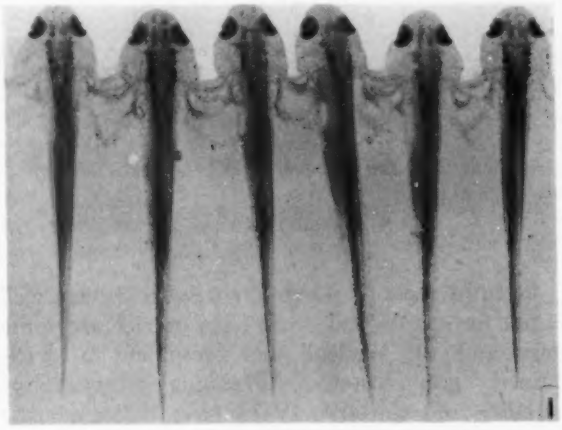


FIG. 1. Six *T. torosus* larvae raised in the laboratory at room temperature from eggs collected in tail bud stage. Photographed twenty-two days after collection, just before tail-clipping. Magnification 4×.

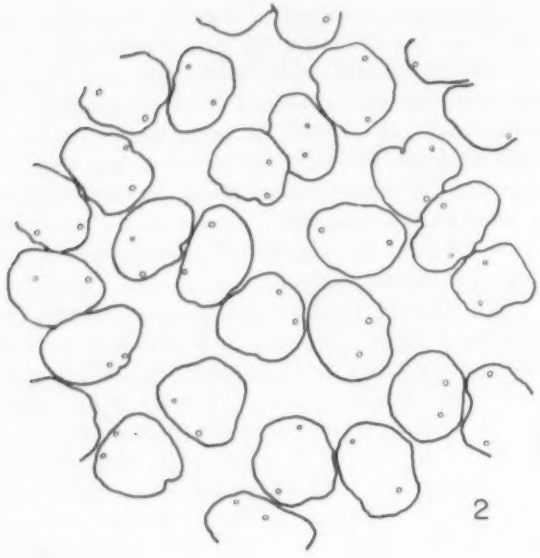
begin, they were isolated in individual paraffined paper ice-cream cups (Hamburger, 1942), in fresh Searsville Lake water. After serial numbers had been assigned to each of the larvae, they were photographed in groups of six to ten (fig. 1). MS-222 or chloretone (both in concentrations of 1:2,000 in distilled water) were used as anaesthetics to immobilize the larvae for photography and for the subsequent amputation of the tail-tips. As a control for the possible effects of these anaesthetics on mitosis, some of the larvae were anaesthetized only in MS-222, some only in chloretone, and some in one of the drugs for the first amputation and in the other for the second.

The clipping of the tail-tip was done in a wax-bottomed Syracuse dish filled with the diluted anaesthetic; sharp, fine-pointed scissors were used and the distal one-third of the tail removed. As rapidly as possible, the tip was transferred in a wide-mouth pipette to a small dish and flooded with fresh fixative (Bouin's solution, modified by the addition of 1 gram of urea and 5 cc. extra acetic acid per 100 cc.). The larva was then returned to the numbered ice-cream cup and allowed to continue development. At the end of approximately 12 days, the regenerated tail-tip was amputated in a similar fashion.

The tips were fixed for 2–6 hours, washed overnight in a large volume of 70 per cent alcohol, stained in Harris's acid haematoxylin and, in some cases, counterstained with erythrosin or acid fuchsin. Best results were obtained when the haematoxylin was diluted 1:2 or 1:3 with distilled water before use. Bluing of the stain was accomplished with repeated changes of tap water to which a few drops of 1 per cent sodium bicarbonate were added. The tips were dehydrated in the usual manner and mounted two per slide in damar or clarite, with No. 1 coverslips.

The tail-tip preparations were studied at a magnification of 210×, and any features of special interest noted on a small "map" of the tip. Camera lucida outline drawings were then made of the nuclei in a single field, using oil immersion (figs. 2, 3). As nearly as possible, corresponding areas on the dorsal side of each tip were drawn, the lateral line organs being used as landmarks. Whenever they were visible, the nucleoli within each nucleus were also drawn. In properly stained *Triturus torosus* tail-tip preparations and especially in the regenerated tips, these structures are quite conspicuous (fig. 4). Drawings were also made at a magnification of 2,100× of mitotic figures of special interest.

The tail-tips were classified with three criteria in mind: (1) variation in nuclear size and nucleolar number in the epithelial cells; (2) presence of abnormal mitotic configurations; and (3) presence of metaphases obviously having more or less than the diploid number of 22 chromosomes. Whenever possible, all three factors were utilized in diagnosis. In this species there seems to be considerable variation in nuclear size within an individual, depending partly on the exact locus from which the nuclear size sample is derived. Nuclei toward the edge of the tail-fin on the dorsal side are usually noticeably larger than those nearer the axis of the tip, or those on the ventral side. Even within a given area, very large interphase nuclei with only two nucleoli were often



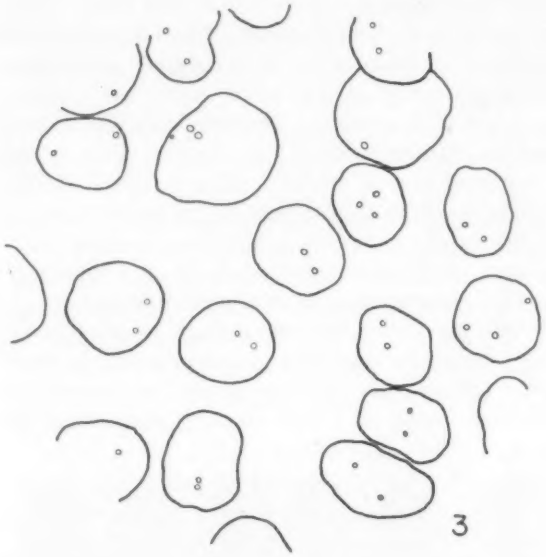


FIG. 2. Typical nuclei and nucleoli of the tail-fin epithelium of a normal diploid larva. Camera lucida outlines. Magnification 330 ×.

FIG. 3. Representative area showing variation of nuclear size and nucleolar number in tail-fin epithelium of another larvae. Camera lucida outlines. Magnification 330 ×.

observed in juxtaposition to uniformly smaller nuclei. Conversely, rather small nuclei sometimes had three or even more nucleoli clearly visible (fig. 3).

It has been our experience that proper feeding of the larvae is essential if good cytological preparations are to be obtained; tail-tips of starved animals usually have very few mitotic figures, and the cells may become badly vacuolated. Efforts were therefore made to maintain optimal feeding conditions, using *Artemia* nauplii for young larvae or, in a few cases, small enchytreid worms. The *Artemia* were cultured from "cysts" in a strong brine, and were washed and concentrated into fresh lake water before being fed to the salamander larvae. Worms made up the bulk of the diet of older larvae.

A few observations also have been made on mitoses in embryonic cells in tissue cultures of *T. torosus*. These hanging-drop coverslip cultures were furnished by Dr. H. E. Lehman. They were explants of portions of the neural crest from embryos collected at the same locales as the material used for tail-tip preparations. The cultures were prepared for cytological study by the general technique described above.

RESULTS

Tail-tips from *Triturus torosus* larvae are well suited for cytological study; the nuclei are quite large and the nucleoli are prominent in well-stained preparations. Previous observations (Henley and Costello, 1947) have indicated that the diploid chromosome number in this species is 22 (fig. 7). Fankhauser (1938, 1939) reports the presence of some mitotic figures in all tail-tip preparations of *T. viridescens*. We have not found this to be the case in *T. torosus*. Many of the first tips and a few of the regenerates had no mitoses present in the epithelium, as is the case in tail-tips of the axolotl (Fankhauser and Humphrey, 1942). In contrast to *T. viridescens* as described by Fankhauser (1938), *T. torosus* tail-tips clipped shortly after hatching but before the feeding stage make rather inferior cytological preparations. The nuclei are not well-rounded and there are few mitotic figures. Regenerating tail-tips are cytologically superior in both uniformity of nuclear outlines and in numbers of mitotic figures.

A summary of the data on the cytological study of first and regenerated tail-tips is presented in table 1. Among the 582 first tips, 423 were

clearly diploid, 105 had variable nucleolar number and/or nuclear size, 53 had abnormal mitoses and one was a chromosomal mosaic. Of the 429 second tips, 284 were normal diploids, 88 had variable nucleolar number and/or nuclear size, 55 had abnormal mitoses, and there were two aneuploid mosaics.

The results indicate that none of the larvae studied was entirely heteroploid, the abnormalities in chromosome number noted having been present in tail-tips that also contained apparently normal diploid nuclei. This condition of chromosomal mosaicism of isolated nuclei in presumably normal material is of interest when compared with the high incidence previously reported (Costello and Henley, 1947) in *T. torosus* embryos shipped from Palo Alto to Chapel Hill. The occurrence in the present "control" study was very much lower (0.1 per cent among the first tips and 0.5 per cent among the regenerated tips, as compared with 33 per cent in regenerated tips of the shipped material). One demonstrable case of mosaicism in the first tips (confirmed by chromosome count) was observed. It was either diploid-hyperdiploid or possibly diploid/triploid. The single observed heteroploid figure was very crowded and difficult to interpret; 22 chromosomes could be counted easily and it was obvious that more were present. Among the regenerated tips, one mosaic appeared to be diploid/hyperdiploid and one possibly diploid/tetraploid. Reliable direct chromosome counts were not possible.

Mitotic abnormalities were observed in a rather high percentage of both first (9.1 per cent) and

TABLE 1

	2N	%	Var. nuc.	%	Abn. mit.	%	Mos.	%	Total
	First tips								
Eggs spawned in laboratory (A, B)	104		25		3		0		132
Los Trancos—raised at 23–26° C. (C)	69		7		3		0		79
Los Trancos—raised at 12–15° C. (E, F)	131		19		7		1		158
	304	82.1%	51	13.8%	13	3.5%	1	0.2%	369
Saratoga (K)	49		13		15		0		77
"Frozen" Los Trancos (L)	41		27		14		0		82
Ukiah (M)	29		14		11		0		54
	119	55.8%	54	25.8%	40	18.7%	0		213
Total first tips	423	72.6%	105	18%	53	9.1%	1	0.1%	582
	Second tips								
Eggs spawned in laboratory (A, B)	71		10		5		0		86
Los Trancos—raised at 23–26° C. (C)	42		18		5		0		65
Los Trancos—raised at 12–15° C. (E, F)	60		27		10		0		97
	173	69.7%	55	22.1%	20	8%	0		248
Saratoga (K)	53		10		6		0		69
"Frozen" Los Trancos (L)	54		10		18		1		83
Ukiah (M)	4		13		11		1		29
	111	61.3%	33	18.2%	35	19.3%	2	1.1%	181
Total second tips	284	66.2%	88	20.5%	55	12.8%	2	0.5%	429

second (12.8 per cent) tips. These abnormalities included "sticky" anaphases or telophases (fig. 12) and metaphase (fig. 9), anaphase or telophase (figs. 13 and 14) spindles from which chromosomes or chromosome fragments had been lost. The lost chromosomal material was apparently incorporated into one or the other of the daughter cells (fig. 16). Presumably this offers a clue to the mode of origin of hypo- and hyperdiploid nuclei. The phenomenon was observed more often in anaphase and telophase configurations than in metaphases.

Masses of relatively uncondensed chromatin were present in some of the preparations, either as isolated configurations (fig. 11) or in association with metaphase figures (fig. 10). It is of interest to note that both of the illustrated examples of this abnormality are in tail-tips from larvae collected as early embryos in very cold water. Similar configurations have been noted in tail-tips from shipped and experimentally cold-treated larvae (unpublished data). Atypical nuclei of the type shown in figure 15 were also noted in preparations from "normal" larvae. These configurations appear to represent the end-product of an unequal division, with a connection persisting between the daughter nuclei.

The incidence of irregularity of nuclear size and nucleolar number was high in both first and regenerated tail-tip preparations. Of the 582 first tips, 105 had nuclei of variable size, or with more or less than the usual two nucleoli present (figs. 3 and 4). Eighty-eight of the 429 second tips showed similar variations. There was no greater correlation than would be expected on the basis of pure chance between the occurrence of variations in nuclear size and/or nucleolar number in first as contrasted with regenerated tail-tips. That is, an individual showing nuclear size variation in the first tail-tip almost invariably produced regenerated tail-tips with nuclei within the normal range of size variation. This is interpreted to indicate that even rather marked variations of nuclear size within the epithelial cells of an individual may occur without necessarily being of significance as an index of mosaic aneuploidy.

Usually the departures from normal nucleolar number involved an addition or loss of no more than one or two nucleoli, and the occurrence of nuclei with such atypical nucleolar number was usually in association with normal nuclei. Only rarely were areas of more than one or two neighboring nuclei with abnormal nucleolar complements noted. The nucleolus in nuclei having only one such "nucleolar organizer" present was frequently very large and conspicuous. There was no direct evidence of such large nucleoli being the result of fusion of the two normally observed (Dearing, 1934; Fankhauser and Humphrey, 1943), but this possibility is not excluded. Ordinarily, only the nuclei within the microscopic field studied for nuclear size were closely examined for nucleolar number, and only those nucleoli that were clearly identifiable were indicated on the camera lucida sketch and included in the tabulation of data. Thus, it is possible that the actual incidence of abnormalities of nucleolar number is higher than the data indicate.

From table 1 it can be seen that larvae developing from egg clutches having a known history of marked temperature variation are characterized by a greater incidence of abnormal mitotic figures. Among the first tips of larvae raised at constant temperature, the occurrence of abnormal mitotic configurations averaged 3.5 per cent. Initial tail-tips clipped from embryos subjected to major temperature variations during their development showed that 18.7 per cent of the larvae had abnormal mitoses. Comparable differences were found between the two groups after study of the second tail-tip preparations (table 1).

Abnormal nuclei of a peculiar appearance (fig. 17) were found in many of the preparations from larvae of the Ukiah, and Saratoga, and the "frozen" Los Trancos collections. These nuclei were characterized by the presence of a highly basophilic periphery and a more lightly staining center. Sometimes basophilic granules were also present in the central region of these nuclei. Often they were found along the edges of the tail-tip, but were also noted nearer the axis. Similar abnormal nuclei were observed in cytological preparations from experimentally cold-treated embryos, and from material shipped in a thermos jug with ice (unpublished data).

There was no noticeable effect on mitosis of the anaesthetics in the concentrations used.

Observations on the tissue-culture preparations suggest that such a technique may be used advantageously in further studies on mitosis in this species. Since the cells are spread out in a single layer on the surface of the coverslip, cytological details are readily seen. The nucleoli are especially prominent (fig. 5) and clearly defined. Furthermore, the relationship of mitotic figures to cell boundaries is readily discernible; it is not

ordinarily possible to study such relationships in tail-tip preparations. An early prophase with nucleoli persisting is shown in figure 6 and an unusually clear metaphase plate in figure 8. The anaphase in figure 18 is likewise well-spread. These normal mitoses are comparable in all respects to those observed in tail-tips (figs. 7, 19, 20). Multinucleate cells are frequently present in the tissue-cultures; their significance is not known.

DISCUSSION

The absence of any cases of polyploidy in this material is surprising, in view of the relatively high incidence noted in larvae of *T. viridescens*. In a group of 2,448 viridescens larvae, Fankhauser (1945) reported a frequency of 1.8 per cent for triploids, 0.28 per cent for pentaploids and 0.16 per cent for haploids. Among the same animals, he found three mosaics. Fankhauser, Crotta, and Perrot (1942) record a 1.1 per cent frequency of natural triploids in *T. pyrrhogaster*. Michalski (1948) reports a 5.1 per cent incidence of triploidy in 412 *Eurycea bislineata* larvae. This is an exceptionally high frequency. Fankhauser (1945) tabulates the occurrence of one triploid, two mosaics, and ten other heteroploids among more than 3,000 untreated axolotl larvae examined. No systematic search for spontaneous heteroploids was made in this species. In a small group of 148 larvae, all of which were examined cytologically, the one triploid was found (Fankhauser and Humphrey, 1942).

Although the eggs from which the *T. torosus* larvae developed were not derived from females stimulated by pituitary injection, it is not valid to assume that the absence of this factor is responsible for the absence of triploid and other polyploid individuals. Fankhauser (1941, 1945) considers the possibility that pituitary injections for stimulating ovulation may contribute to the production of the exceptional individuals he observed, and concludes that such hormonal stimulation is probably not involved. No definite evidence on the subject is afforded by the present study.

It is difficult to account for the absence of polyploidy. One could postulate that balanced lethal factors are present in the diploids of this species. Heteroploids, having an extra dose of one or more of the lethal genes, would die early in development due to a lethal imbalance. Conversely, one could postulate that *T. granulosus* is marked by a relative freedom from lethal factors, deficiencies and duplications, as evidenced by the long survival of haploid larvae (Costello, unpublished observations).

It is questionable whether the data relating to spontaneous heteroploidy presented here are strictly comparable to those tabulated by Fankhauser (1945: 33). Fankhauser describes the general procedure followed in his laboratory (p. 29):

> In practice, all larvae are examined and classified with regard to their pigment pattern as early as possible. All suspicious looking animals are then tail-clipped for a cytological check, the result of which very often agrees with the prediction; of the larvae with unmistakably diploid pigment pattern only a small number are tail-clipped to furnish control preparations for comparison.

It is likely that cytological study of many larvae which appear normal would reveal a higher incidence of polyploidy and especially of mosaicism; this possibility is pointed out by Fankhauser (1945). Our data for *T. torosus* are based on a careful cytological examination of the tail-tips of all larvae, regardless of their appearance.

In other forms (Barber and Callan, 1943), low temperatures are known to result in the production of "sticky" anaphases and telophases, such as those we have observed. It may be assumed that the temperature factor alone is not responsible, since such abnormalities of mitosis were also observed in larvae which were known to have been raised within a constant temperature range. However, the incidence of abnormal mitosis was higher in those larvae which were not raised at constant temperature, indicating that temperature shock may also have played a role. Genetically, such "sticky" configurations would be expected to result in the production of daughter cells having a deficiency and an excess of chromosomes respectively, or the lagging chromosome material may simply be expelled from the spindle into the cytoplasm.

The developmental effects of a few "sticky" mitoses and of configurations in which chromosomes or chromosome fragments are lost from the spindle must be slight; the larvae are, to all appearances, entirely normal, except for the occurrence of small necrotic areas on the tail-tip. In tail-tips stained with Harris's acid haematoxylin, these areas take the form of homogeneous globules of basophilic material. However, when the tips are stained in Mallory's triple stain, distinct color

variations are discernible in the globules. There are also differences in staining reaction between the interphase nuclei, which are light red, and the mitotic figures which appear orange at metaphase and deep rose at prophase and anaphase or telophase. The globular necrotic products range in color from orange to a bright scarlet. This color gradation also may occur within a single globule. The globules may represent chromatin lost from the spindle, but in some cases are clearly due to the partial or complete degeneration of a whole nucleus. This nuclear necrosis, together with fragmentation of resting nuclei, is described by Costello and Henley (1947) as one of the causes of variations in nuclear size in the abnormal shipped material. It is possible that such necrotic areas are resorbed in animals where they are not too numerous and the areas filled in by cell replacement.

It was noted above that there were fewer instances of chromosomes lost from metaphase spindles than from anaphase or telophase spindles. Presumably, this condition is more apparent at anaphase and telophase because the chromosomes or chromosome fragments lacking kinetochores would be left behind and therefore distinct from those of the polar groups.

All these cases of mitotic abnormality are suggestive of the mode of origin of the few mosaics described. Since the aneuploid figures observed were almost invariably isolated among groups of normal nuclei rather than occurring as larger mosaic patches, they either must lack an ancestry of aneuploidy and represent terminal products which fail to divide further, or represent the beginning of an aneuploid area.

The incidence of mosaicism in the larvae studied here is comparable to that reported by other investigators for other species of salamanders. The aneuploid constituents of the mosaics may be presumed to arise as the result of the loss of chromosomes from the spindle, or of failure of chromosomal division. No multipolar spindles were observed in this study, but such a mechanism for the production of aneuploid figures is not excluded. Tripolar and tetrapolar figures have been reported (Costello and Henley, 1947) in larval tail-tips from shipped *T. torosus* material. This shipped material showed also a higher incidence of aneuploid mosaicism.

The effects on development of such conditions of chromosomal mosaicism involving small areas are, like those of "sticky" anaphases, presumably slight, or at least very localized. There was no visible correlation between morphological abnormality and the presence of chromosomal mosaicism.

The great variation in nuclear size noted in many of the tail-tip preparations is probably not indicative of a higher incidence of chromosomal mosaicism than could be confirmed by direct nucleolar or chromosome counts. There was no correlation between the occurrence of variations in nuclear size in first and regenerated tail-tips. Sometimes the metaphase plates (ordinarily used for making chromosome counts) are so crowded that a precise interpretation of each chromosome constituent is impossible. Thus, many figures classified as diploid may actually be hypo- or hyperdiploid. Some tail-tips have a remarkable

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Photomicrographs 4–11 were taken at a magnification of approximately 1,200 ×, and reduced by the engraver to 1,100 ×.

FIG. 4. Interphase nuclei from tail-tip of a larva collected at Saratoga from very cold water. Note the extreme variation in size. The smaller nuclei (in one of which two nucleoli are clearly visible) are within the normal range of size variation. Only three nucleoli are present in the large nucleus, although it appears to be at least twice as large as the diploid.

FIG. 5. A single young pigment cell in tissue culture. The nucleoli are very prominent. Yolk material is visible in the lightly outlined cell body.

FIG. 6. An early prophase in a cell in tissue culture.

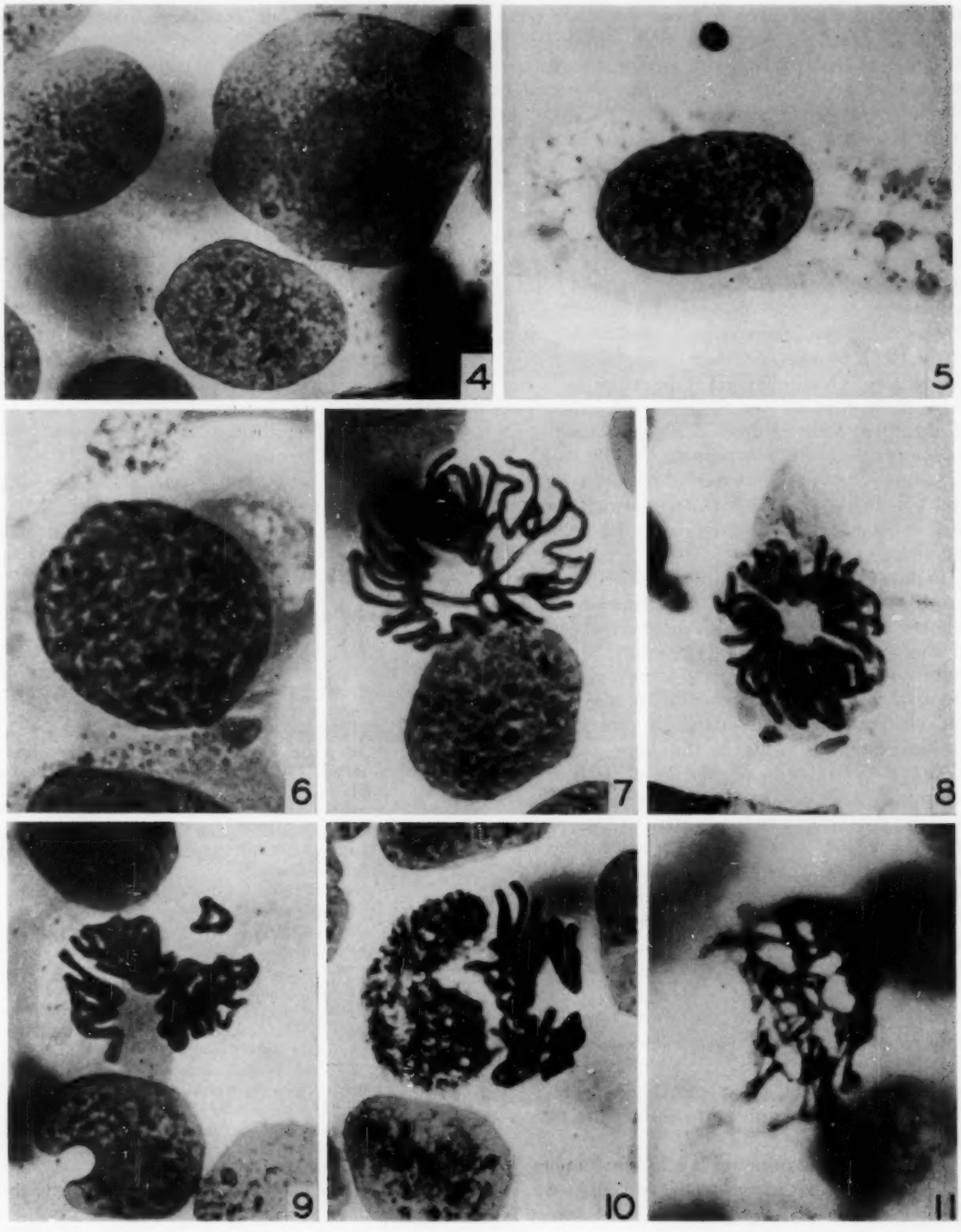
FIG. 7. A normal diploid metaphase in the epithelium of a regenerated tail-tip.

FIG. 8. A normal diploid metaphase in the same tissue culture as the prophase shown in figure 6. Orientation of the chromosomes in a ring is typical in polar views of metaphase plates, both in tail-tip epithelium and in tissue culture.

FIG. 9. An atypical metaphase in the tail-tip epithelium of a larvae from the "frozen" embryos collected at Los Trancos. The chromosomes appear to be split and one chromosome has apparently lost its spindle connection. The adjacent interphase nucleus was indented by an oil globule; this is a characteristic feature of tail-tips cut from young larvae before yolk resorption is complete.

FIG. 10. An abnormal metaphase with adjacent chromatin mass in the tail-tip epithelium of a larva collected from very cold water. The chromosomes in the metaphase are too crowded for an accurate count to be made. Therefore, it is impossible to ascertain whether the chromatin represents uncondensed chromosomes of the metaphase.

FIG. 11. An abnormal mass of chromatin in the regenerated tail-tip epithelium of a larva from the "frozen" embryos collected at Los Trancos. There has been some condensation of the chromatin but no normal formation of chromosomes.



FIGS. 4–11

unformity of nuclear size, even though they are the same age and have received the same treatment as those showing noticeable variation. It is doubtful that nuclear size determinations, per se, are of great importance in the detection of chromosomal mosaics in this species. However, used in conjunction with decisive chromosome counts, they may be of some diagnostic value.

The significance of the observed variations in nucleolar number is problematical. Dearing (1934) described the formation of the nucleoli from subterminal achromatic regions of two V-shaped chromosomes in epithelial cells of *Ambystoma tigrinum*. He was able to follow these nucleolar condensations from anaphase through prophase, and to observe their reappearance after metaphase. One individual is described as having three nucleoli in each of the epithelial cells. Two of the three were located in the V-shaped chromosomes; the third was near the middle of one of the arms of a long U-shaped chromosome. Several counts of metaphase plates showed only the diploid number of chromosomes (28) in this individual.

Fankhauser and Humphrey (1943) have studied the relation between nucleolar number and the number of haploid chromosome sets in the tail-tip of the axolotl. They conclude that "the maximum number of nucleoli visible in the nuclei of any individual corresponds to the number of haploid chromosome sets" (p. 350). Furthermore, the suggestion is made in the same paper that there is a marked tendency for the nucleoli to fuse, confirming the observations of Dearing (1934). If this is so, the cases reported in the present study of nuclei with either one or two nucleoli occurring in the same tip probably represent normal diploid tissues and not mosaics. However, Fankhauser and Humphrey (1943) report the presence in a hypodiploid individual of only one nucleolus in each nucleus. Briggs (1947) illustrates three nucleoli in nuclei of triploid *R. pipiens* larvae. *T. torosus* tail-tips were observed in which some nuclei had two nucleoli while others had three or even more. Presumably, these are more likely to represent cases of mosaicism, even though all mitotic figures present on the tip appeared to be diploid.

The diagnostic value of nucleolar number is undoubtedly great in cases of euploidy, where addition or loss of whole sets of chromosomes is involved. However, in suspected cases of aneuploidy, direct chromosome counts of well-spread figures are the only reliable criteria. This would also apply to mosaic conditions, such as those described here.

In general, the results of this survey indicate that radical mitotic anomalies similar to those observed in shipped *T. torosus* larvae have a low incidence in a "natural population." However, even minor temperature changes may have effects in producing less pronounced abnormalities of the mitotic mechanism in larval epithelial cells of the salamander. Whether these effects are also expressed in other tissues is not shown by our results. Fischberg (1947) is of the opinion that temperature shocks in nature may produce triploidy and other euploid and aneuploid chromosomal conditions, depending on the stage of development at which the cold shock is operative. Further studies on the effects of temperature on mitosis in larval epithelium are in progress.

Photomicrographs 12–20 were taken at a magnification of 1,200 × and reproduced without reduction.

FIG. 12. A "sticky" anaphase in the epithelium of a regenerated tail-tip from a larva collected and raised at 12° C. This type of abnormality was quite frequently encountered, especially in larvae subjected to marked temperature changes during their development.

FIG. 13. A telophase with lagging chromosome or chromosome fragment. From the regenerated tail-tip epithelium of a larva collected in very cold water. The outline of the cytoplasmic area is discernible, with the beginning of cytokinesis occurring.

FIG. 14. A telophase with a lagging chromosome fragment in tail-tip epithelium from a larva collected and raised at 12° C.

FIG. 15. A late telophase with persistent connection between the asymmetrical daughter nuclei. From the regenerated tail-tip epithelium of a larva collected from very cold water.

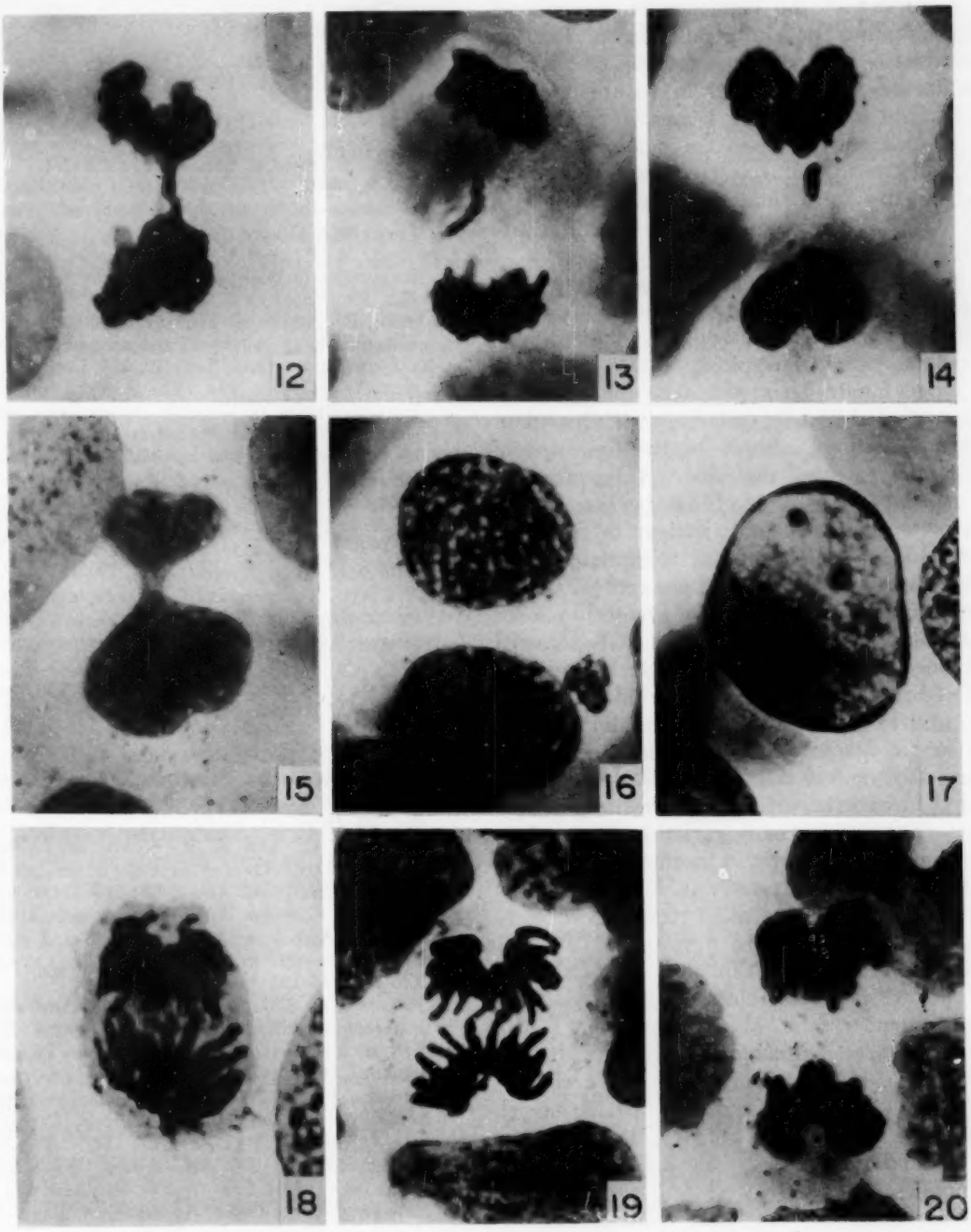
FIG. 16. A late telophase with a fragment of chromatin material (small nuclear vesicle) incorporated into one of the daughter cells. From the regenerated tail-tip epithelium of a larva collected in very cold water.

FIG. 17. An abnormal nucleus in the regenerated tail-tip epithelium of a larva from the "frozen" embryos collected at Los Trancos. Note the basophilic periphery and the more lightly staining center. The dark granules are not nucleoli although their superficial resemblance to such structures is great.

FIG. 18. A normal anaphase in a cell of explanted neural crest material. The outline of the cell body is clearly seen. From the same preparation as the prophase and metaphase in figures 6 and 8.

FIG. 19. Photomicrograph of a normal anaphase in the tail-tip epithelium.

FIG. 20. A normal telophase in the tail-tip epithelium. The small granules in the spindle are embryonic pigment.



FIGS. 12–20

SUMMARY

1. A survey of the incidence of spontaneous heteroploidy in a "natural population" of *Triturus torosus* has been made on a total of 582 larvae. These larvae were collected in nature as early embryos and raised in the laboratory. Tail-tips were clipped and prepared for cytological study when yolk resorption was complete; the regenerated tail-tips were similarly clipped at the end of 12 days. Five hundred eighty-two first tips and 429 regenerated tips have been studied.

2. No polyploid or haploid larvae were found. Three individuals were diagnosed as probable mosaics; two were apparently diploid/hyperdiploid and one was diploid/tetraploid.

3. Three hundred sixty-nine larvae were collected and raised under relatively uniform temperature conditions. Study of the first tips of these larvae revealed that 304 (82.1 per cent) were normal diploids, 51 (13.8 per cent) had nuclei of variable size or variations in nucleolar number, 13 (3.5 per cent) had abnormal mitoses and there was one mosaic (0.2 per cent). Of the 248 regenerated tips, 173 (69.7 per cent) were normal diploids, 55 (22.1 per cent) had nuclei of variable size or variations in nucleolar number, and 20 (8 per cent) had abnormal mitoses.

4. Two hundred thirteen additional larvae were raised within a constant temperature range from eggs collected in very cold water; 82 of these eggs appeared to have been frozen at the time of collection. The incidence of variations in nuclear size and nucleolar number, abnormal mitoses and mosaicism in these larvae was higher than in those not subjected to marked temperature variation. Of the total of 213 first tips, 119 (55.8 per cent) were normal diploids, 54 (25.8 per cent) had nuclei of variable size or variations in nucleolar number, and 40 (18.7 per cent) had abnormal mitoses. Among 181 regenerated tips of this group, 111 (61.3 per cent) were normal diploids, 33 (18.2 per cent) had variable nuclei or variations in nucleolar number, 35 (19.3 per cent) had abnormal mitoses, and 2 (1.1 per cent) were mosaics.

5. It is concluded that even relatively minor temperature fluctuations may produce mitotic abnormalities in epithelial cells of *T. torosus* larvae. However, these abnormalities are not as radical as those noted in larvae subjected to extreme temperature shock.

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PRE-NINETEENTH CENTURY STAGE IRISH AND WELSH PRONUNCIATION

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STAGE dialect is of the theatre. It has to be immediately intelligible to an audience which will usually have no more than a casual acquaintance with the type of speech represented. It is therefore concerned to produce an illusion, not to reproduce dialect accurately. It makes an approximation by indicating some dialect pronunciations and introducing other features, but is careful to remain intelligible. As this approximation has to take into account such knowledge as the audience may have, it must to that extent be based on reality; or at least it must conform to a convention (itself based ultimately on reality) which the audience accepts. Conventions do not suddenly appear full-grown; they have to develop. *Caeteris paribus*, therefore, stage dialects tend to move from realism towards convention.

During the period under review no even moderately adequate phonetic notation existed; nor, if it had, would dramatists have used it. The play-texts are designed to give pointers to actors or to suggest verisimilitude to readers; only very rarely do they attempt accuracy and consistency. Irregular spelling over the greater part of the period does not make things easier. The printed dialect parts indicate that at certain points the stage dialects differed definitely and noticeably, though not consistently, from standard (or rather, London) English. These points of difference are reflections of facts about the actual dialects.

Examination of other aspects of the Irish and Welsh stage characters shows that each group tends to pass from comparative realism to distinct conventionality.[1] The dialect-speaking stage Irishman begins in 1596 (or earlier) in *Captain Thomas Stukeley* and becomes increasingly conventional, especially after 1760. In 1592 the earliest stage Welshmen (in *A Knack to Know a Knave* and Nashe's *Summer's Last Will and Testament*) already show signs of conventionality; they are fully conventional by the end of the seventeenth century, after which interest in them declines greatly. Broadly speaking, these observations are supported by the results of analysing the indications of pronunciation. Reliance on a few repeated dialecticisms and the restriction of a specific dialecticism to one (or a very few words) suggest convention; the converse of these suggests a certain rough realism.

The general view of English pronunciation followed is that of H. C. Wyld.[2] It is convenient to divide the whole period into three sections which broadly approximate to stages in the development of the characters and their speech. These are: A, *ante* 1660; B, 1660–1760; C, 1760–1800.

Differences of pronunciation indicated in the plays are treated one by one in the analyses below. The fractions given under A, B, and C (or subdivisions) show the proportion of plays containing the particular indication to the total of plays during these years which mark the dialect pronunciation at all. Each heading indicates the substitution for standard English which would probably have been heard on the stage if the actors followed the phonetic implications of the texts.

I. IRISH

The differences between "Anglo-Irish" and standard English have been examined in detail and commented upon by Professor J. J. Hogan.[3] Some of his evidence is drawn from dramatic material, but most is from other sources. If possible, each point has been referred to his work.

For the Irish, period B is subdivided into (1) 1660–1710, (2) 1710–1760. From 1700 and especially after 1760 Irish parts were increasingly played by Irish actors who were presumably less dependent on indications given by the play-

[1] *Cf.* Bartley, J. O., The development of a stock character, I (Irish), *Mod. Lang. Rev.* **37** (4): 438–447, 1942, II and III (Welsh and Scottish), *Mod. Lang. Rev.* **38** (4): 279–288, 1943.

[2] *History of Colloquial English*, 2nd ed., Oxford, Blackwell, 1936. Cited as "Wyld," references are to pages.

[3] In *The English language in Ireland*, Dublin, Educational Co. of Ireland, 1927 and *An outline of English philology, chiefly for Irish students*, Dublin, Educational Co. of Ireland, 1934. Cited as "Lang." and "Phil.," references are to paragraphs.

wrights. But the texts are our authority for what both writers and audience were prepared to accept as a representation of the Irish "brogue."

1(*a*). [*ʃ*] for [*s*]. (*cf.* Lang. 100, Phil. 7*b*)

Many Irish speakers levelled English [*s*] and [*ʃ*] under Irish [*ʃ*]. Playwrights often spell *sh* = English [*ʃ*] for *s*, e.g., "shitty" = city, "shelfe" = self.

A. 8/12. The substitutions show no bias towards any particular word or kind of word.
B. (1) 14/16; (2) 15/16. The substitution occurs most frequently in "shoul" and "shalvation," words found in "characteristic" Irish oaths. After 1710 it is decreasingly frequent in words other than these.
C. 22/97. The substitutions are almost entirely confined to "shoul."

1(*b*). [*ʃ*] for [*ʒ*]. (*cf.* Lang. 101, Phil. 7*b*)

Irish speakers in periods earlier than the Modern usually employed a breath sound for English [*ʒ*]; this was often Irish [*ʃ*]. Playwrights tend to spell *sh* = English [*ʃ*] for [*ʒ*], e.g., "cushin" = cousin.

A. 6/12.
B. (1) 7/16; (2) 2/16.
C. 1/97 (in 1761).

1(*c*). [*ʃ*], occasionally [*tʃ*], for [*dʒ*]. (*cf.* Lang. 101, Phil. 7*b*)

[*ʒ*] does not exist in Gaelic, and Irish speakers therefore tended to replace [*dʒ*] by Irish [*ʃ*]. Playwrights spell *sh* = English [*ʃ*] for *j* = [*dʒ*], e.g., "shudge" = judge.

A. 7/12.
B. (1) 6/16; (2) 2/16. The substitution tends to be confined to "shentleman."

1(*d*). [*ʃ*] for [*tʃ*]. (*cf.* Lang. 100)

[*tʃ*] was reduced to Irish [*ʃ*] in earlier Anglo-Irish. Playwrights sometimes spell *sh* = English [*ʃ*] for *ch* = [*tʃ*], e.g., "sush" = such.

A. 4/12.
B. (1) 5/16; (2) 1/16 (in 1739).

1(*e*). Gaelic "slender" and "broad" *s*.

In Gaelic [*s*] is followed by back, and [*ʃ*] by front vowels. A carrying over of this into Irish-English may sometimes have been noticed by playwrights. In *Stukeley* we find "shecretary," "cresh" = Christ, "blesh," and "sall." This play does not otherwise modify *s* or *sh*, which suggests possible accurate observation of some particular speaker or group. Certain spellings in Randolph's *Hey for Honesty* (1629) and Michelburne's *Ireland Preserved* (1705) suggest the possibility of either a less accurate representation of such a speech habit, or indication of a less precise reflection in English of the Gaelic usage.

2(*a*). [*d*] or [*t*] for [*ð*]. (Lang. 91, Phil. 6*b*).

[*ð*] does not occur in Gaelic and in past and present popular Anglo-Irish is replaced by the Irish voiced broad fan-stop [*D*], or, in Southwest districts, by [*d*]. Playwrights spell *d* or *t* = [*d*] or [*t*] for *th* = [*ð*], e.g., "dat" and "tat" = that

A. 11/12.
B. (1) 13/16; (2) 8/16.
C. 14/97.

2(*b*). [*t*] for [*θ*]. (*cf.* Lang. 91, Phil. 6*b*)

[*θ*] does not occur in Gaelic and (as above) is replaced by the voiceless broad fan-stop [*T*] or by [*t*]. Playwrights spell *t* = [*t*] for *th* = [*θ*].

A. 11/12. Often in "fait," "trot, "and "tousand."
B. (1) 7/16; (2) 8/16. Most frequently in "fait" and "tousand."
C. 30/97. Usually in "fait" and "tunder."

3. Gaelic [*f*] and [*v*] are bilabial, corresponding exactly, unlike their English equivalents, with [*p*] and [*b*]. Today where Gaelic influence is strong (as it certainly was throughout Ireland in A and B(1), if less thereafter) Irish speakers substitute these sounds for English [*hw*] and [*w*].

3(*a*). [*f*] for [*hw*]. (*cf.* Lang. 95, Phil. 6*b*, Wyld, 312)

Playwrights spell *f* or *ph* = [*f*] for *wh* = [*hw*], e.g., "feete" = white.

A. 5/12.
B. (1) 7/16; (2) 9/16.
C. 2/97.

3(*b*). [*v*], rarely [*f*], for [*w*]. (*cf.* Lang. 94, Phil. 6*b*, Wyld 312)

Playwrights spell *v* = [*v*] for *w* = [*w*], e.g., "vil" = will.

A. 5/12.
B. (1) 5/16; (2) 1/16 (in 1737).
C. 2/97.

(The bilabial [v] was indicated by spelling *b* in four plays, in 1636, 1763, 1772, and 1776.)

4 [*d*] for final [*t*]. (*cf.* Lang. 93)

Among Irish speakers, "finally [*t*] is weak, perhaps also voiced." Two playwrights have written *d* = [*d*] for final *t* = [*t*], e.g., "blankead" in *Stukeley* and "dad" (= that) in *Folly of Priestcraft* (1690).

5. [*t*] for final [*d*]. (*cf.* Lang. 92)

"In Anglo-Irish there is a strong tendency to unvoice [*d*] finally," and playwrights spell, e.g., "wort" = word.

A. 4/12.
B. (1) nil; (2) 1/16 (in 1713).
C. 1/97 (in 1776).

6. [*p*] for [*b*]. (*cf.* Lang. 89)

"Irish weak voicing" of [*b*] is marked by playwrights spelling *p* = [*p*] for *b* = [*b*], e.g., "pelly" = belly.

A. 2/12.
B. (1) 1/16 (in 1663); (2) 1/16 (in 1718).

7. "ax" for ask.

C. 10/97. This metathesis, widely distributed at all periods, was apparently thought characteristically Irish by some people.

8. [*i*] for one or other diphthong from ME *ī*. (*cf.* Lang. 80, Wyld 209, 225)

Up to the early eighteenth century, Irish speakers used [*i*] for English diphthongs from ME *ī*, but less frequently as time went on. Playwrights use such spellings as "dree" = dry (also *iee* and *ie* = [*i*] for *i* or *y* = diphthong). "Creest" = [*krist*] for Christ may merely reproduce the Gaelic *Críost* which is pronounced thus.

A. 10/12.
B. (1) 9/16; (2) 2/16.

9. [*æ*], [*æ:*], or [ɛ] for [*e*] from ME *a* and *ai*. (*cf.* Lang. 69, Wyld 195–6, 205, 247, 298)

Up to and including the earlier eighteenth century, some Irish speakers used a vowel [*æ:*] where Englishmen used [*e*] (from ME *a* and *ai*). Playwrights mark this by spellings like "fat," "faat," and "fet" = faith, suggesting respectively [*æ*], [*æ:*], and [ɛ].

A. 4/12. Always in the ejaculation "faith."
B. (1) 9/16; (2) 4/16. It occurs in a variety of words, suggesting a certain realism in the earlier plays at least.
C. 2/97. In "faith" only.

10. [*I*] for [ɛ]. (*cf.* Lang. 71, Phil. 15, Wyld 228]

"The short *e* is normally raised in Anglo-Irish towards high-front-slack." There was a tendency among English speakers, which persisted till the early eighteenth century, to raise [ɛ] to [*I*], chiefly before [*n*] + consonant, also [*s*], and more rarely [*l*]. Hogan's few examples, and the evidence of the plays in C, suggest that the Irish raising of [ɛ] occurred most frequently before nasals, [*s*], and [*l*]; e.g., spellings like "ilbow," "pincil," "bliss." The substitution is also often found before [*v*], e.g., "iver."

A. 3/12.
B. nil.
C. 12/97.

Welsh Embassador (*ca.* 1623) has "virmine" for vermin. This must be a representation of the Irish raising of ME *e*, since the sound was retained in Anglo-Irish. The figures above do not take account of the numerous "divils," especially in C, possibly the result of Irish adoption of the English variant with [*I*] from the ME forms with *ē*, reinforced by the tendency noted. There are also indications of Irish adoption, possibly under the influence of Scottish settlers in the north, of another English variant, with [*i*], e.g., "deel" in *Folly of Priestcraft* (1690) and Farquhar's *Twin Rivals* (1702).

11. [ɛ] or [*æ*] for [*I*]. (*cf.* Lang. 81, Phil. 15)

Many Irish speakers lowered [*I*] to the mid-position. Playwrights sometimes spell *e* or *a* = [ɛ] or [*æ*] for *i* = [*I*], e.g., "lettle," "shackness."

A. 6/12.
B. (1) 2/16; (2) 1/16 (in 1713).
C. 1/97 (in 1768).

12. [*æ:*] or [*e*] for [*æ*] or [ɔ] (ME *a*). (*cf.* Lang. 36, 68, Wyld 201)

Hogan finds that in the Forth dialect of Anglo-Irish ME *a* was represented by a half-long advanced if not front vowel, and notes that the dialects of Forth and Fingal covered a larger area in the sixteenth and seventeenth centuries than later. Playwrights spell "fate," "faat," and "phaat" = what, and "daat" = that.

A. 2/12.
B. (1) 4/16; (2) 2/16.
C. 1/16 (in 1797).

It may be, however, that similar spellings of what, warm, and wash, represent the modern Anglo-Irish unrounding of ModE [ɔ] after [*hw*] and [*w*]. If so, there are no occurrences after 1710. Farquhar has "taaking" (= talking) and Cibber "smaal." These may be indications not of the half-long Forth vowel but of the unrounded Anglo-Irish vowel in the combination [*al*], in which case only the unroundedness is being indicated.

13. [æ] or [a] (slightly rounded) for ME *o*, ModE [ɔ]. (*cf.* Lang. 77, Phil. 15, Wyld 240)

Me *o* is unrounded in Anglo-Irish, becoming low-back-slack. Playwrights spell "trat" = troth.

A. 2/12.
B. nil.
C. 4/97.

This pronunciation's infrequent indication and complete absence from B, in spite of its extreme noticeability in present-day Irish speech, may be because it was once a fashionable English pronunciation which reached its height about 1700.

14. [ɔ] or [ɔ:] for [æ] (Me *a*) or [æ:] (Me *a* before [*s*], [*f*], [*θ*]). (*cf.* Lang. 64, 66, Phil. 15, Wyld 203)

"ME *a* seems to be kept more or less unaltered in Anglo-Irish." Before [*s*], [*f*], and [*θ*], it remains unlengthened. The playwrights spell *o* = [ɔ], or more usually *au*, *aw* = [ɔ:], e.g., "lond," "aund," and "hawnd."

A. 2/12.
B. (1) 7/16.

15. [*i*] for [*I*]. (*cf.* Lang. 81, Phil. 15)

Some Irish speakers use a sound "high-front-slack, higher and more definitely front than Standard *E*, and also tending to be tense." Playwrights spell *ee* = [*i*] for *i* = [*I*], e.g., "peepins" = pippins.

A. 5/12.

16. [*u*] for [a*U*]. (*cf.* Lang. 78, Wyld 230)

Some Irish speakers, up to the early eighteenth century, though few by then, used for ME *ū* "a transition diphthong which sounded like [*u*] to English observers." This is noticed in *Stukeley* and *Twin Rivals* by spelling *oo* = [*u*], e.g., "croon" = crown.
ME *ū* before [*r*] was retained in Anglo-Irish during the eighteenth century (and may still be heard), e.g., "coort" = court, in Colman's *New Brooms* (1776).

17. [*e*] or [æ:] for [*i*]. (*cf.* Lang. 74, Wyld 209)

From the fifteenth century words which in ME had *e* were pronounced with either [*i*] or [*e*], the latter probably among the better educated. The plays seem to show that in the late seventeenth century these speakers began to abandon the [*e*] type for the [*i*] type. The [*e*] type was (and still is) retained in Ireland, and by the later eighteenth century was regarded as a definite mark of Irish-English, and was indicated by spellings like "mane" = mean, and "shpaaking" = speaking.

B. (1) 2/16; (2) 7/16.
C. 48/97. Indications, though widely scattered and including a number of pronunciations such as "fataguing," "oblaged," "belave," "agraable," and "saam" (= seem), which it is improbable that any Irishman ever used naturally, tend to appear in certain words, which, in order of frequency, are "azy," "cratur" = creature, "Jasus," "spake," "lave," "grate" (= great), and "plase."

18. [ʌ] for [*U*]. (*cf.* Lang. 75, 79, Wyld 236–239)

Many Irish speakers retain the early Modern shortening of ME *ō*, and this is indicated in the plays by spellings like "luck" = look, "fut" = foot, accurately reflecting the Irish vowel. Foote represents his name in Irish mouths as "Fot" and "Fote," presumably intending [ʌ]. The distribution of [ʌ], [*U*], and [*u*] (all from ME *ō*) was less settled in the sixteenth and seventeenth centuries, which perhaps explains the virtual absence of [ʌ]

before C. (It is marked in Murphy's *Apprentice*, 1756.)

19. [*u*] for [ʌ]. (*cf.* Lang. 79, Wyld 232)

"Earlier Anglo-Irish had a sound different from that of Standard E ([ʌ] from ME *u*) and possibly nearer to the ME vowel." Thomas Sheridan's *Brave Irishman* (1737) has "goon" = gun.

20. [ɔ] for [ɛ]. (*cf.* Lang. 71, Phil. 15)

This appears to be indicated, albeit frequently, in only one word, the playwrights spelling "jontleman" = gentleman. Can the [ɔ] be a rough approximation to Dublin [æ] for English [ɛ]? In Richardson's *Fugitive* (1794) we find "gantleman" and in Foote's *Cozeners* (1774) "batter" = better. *Ireland Preserved* has "shantleman," "bad," "batter."

C. 18/97.

21. [a*U*] for [*o*] or [*o U*] before [*l*]. (*cf.* Lang. 69, Wyld 195)

The ME combination of o^2 + [*l*] produces, in many Irish speakers, a diphthong mid-flat-tense + high-back-round. Playwrights spell *ou* or *ow* = (presumably) [a*U*].

B. The isolated spellings "auld," "oold," and "saoul" in 1681, 1702, and 1752, may indicate some approximation to the Irish diphthong.
C. 19/97. Almost always in "ould"; rarely in "bould," "tould," and "hould."

22. [ɔ:] for [*e*]. (*cf.* Lang. 69, Wyld 195)

Up to the early eighteenth century some Irish speakers retained ME *a* unaltered. Playwrights spell *au* = [ɔ:], e.g., "tauke" = take.

A. 1/12. ("waures" = wares, Dekker's *Honest Whore*, 1605).
B. (1) 5/16; (2) 1/16.

23. [æ:] or [æ*r*] for [ɜ·] or [ɜ*r*]. (*cf.* Lang. 72, Wyld 213 ff)

While the [æ:] or [æ*r*] form from ME *er* was prevalent in Standard E, the Irish [ɛ*r*] would not have been very noticeable, but when the [æ:] form was supplanted (in all but a few words), by the [ɜ] form, it would have become noticeable. Being near to the English [æ:] form, it would have been most easily represented by spelling *ar*—indeed, no other spelling would have conveyed [ɛ*r*] to mid-eighteenth century Englishmen. The *ar* spelling apparently then became a convention in writing Irish parts and was retained when it would have come to suggest not [ɛ*r*] or [æ:] but [*a*]. (Alternatively, some Irish speakers may have retained the [æ:] forms and their later development [*a*] in a far larger number of words than Englishmen.)

B. (2) 2/16.
C. 16/97. Most frequent in "sarve" = serve, and related words.

24. Unrounded vowel for [ɔ] in because (ME *au*). (*cf.* Lang. 83, Phil. 15, Wyld 251)

The characteristic Irish sounds for ME and early Mod [a*U*] are (1) low-back-slack-long and (2) this sound considerably fronted to low-front [æ:]. Playwrights from 1768 onwards spell "becase" (also "becaase") thereby indicating at least the unrounded quality of the Irish sound.

C. 9/97. Although this substitution is made by Irish speakers in many words (e.g. author) the playwrights practically confine it to because. Brooke's *Contending Brothers* (1778) indicates the unrounded Irish vowel in "laa" = law; Jonson had "becasht" (= because) in the *Irish Masque* (1613).

The above analysis shows that the pronunciation given to the stage Irishman becomes increasingly conventional. This is borne out by the decreasing average number of dialect points indicated in the plays of successive periods (A, 8.5; B(1), 6.5; B(2), 4.0; C, 3.0) and by the increasing tendency to confine indications to certain words. It might be thought that the decline in the number of indications in B(2) and C is due to the observable increase in the proportion of Irish upper-class characters. While it is true that the stage was then often accused of making Irish gentlemen speak like haymakers, it is also true—a reminder for which we are indebted to Professor Hogan—that in the eighteenth century and earlier, especially in more rural areas, the distinction between upper and lower class speech was not so marked as it later became.

Five plays call for special note: *Stukeley*, Jonson's *Irish Masque* and *Bartholomew Fair* (1617), *Ireland Preserved*, and *Contending Brothers*.

Stukeley is remarkable for accuracy if not consistency, and it is the only play not certainly by

an Irishman which shows unquestionable knowledge of Gaelic usage. Twelve of the above points are definitely indicated in one brief scene, and some of them are such as would have been apparent only to a keen observer, e.g., 1(*e*), and spellings like "blankeads" and "forgeats" which suggest the final (or rather, equal) stress of the Forth and Fingal dialects, also noted by Stanyhurst—"Most commonlie in words of two syllables they give the last the accent: as they saie, markeat, baskeat, gossoupe . . . Robart."[4] The form "Cresh" (= Christ) is noteworthy. Original Anglo-Irish may have had [*krIst*] derived from the OE nominative *crīst*. "Cresh" may then represent this short-vowelled form with the [*I*] lowered to [ɛ] and the Irish 'slender' [*ʃ*] substituted for English [*s*].

Irish Masque notes 16 and *Bartholomew Fair* 13 of the points. 1 (*a*, *b*, and *d*), 2 (*a* and *b*), and 3 (*a* and *b*) are used with striking consistency in the first and only less so in the second. Both plays frequently (*Irish Masque* all but consistently) spell *ai* or *ay* in words like "graish," "faish," "tayke," which were usually written with *a*. In Chapter 5 of the *English Grammar* Jonson makes it clear that he took *ai* to signify a diphthong: these spellings probably reflect Irish diphthongization of the English vowel (*cf.* Lang. 69). *Irish Masque* also indicates the characteristic Irish aspiration of consonants (*cf.* Lang. 37, Phil. 10) in the spellings "Phatrick" and "prhetee" = prithee. The spellings "Yamish" (= James) and "mayesty" may, as Hogan suggests (Lang. 101) represent Irish [*ʃ*] voiced; this, or *sh* = [*ʃ*] for *j* = [*dʒ*], is consistently used.[5]

In *Ireland Preserved* thirteen points are noted with fair consistency. Michelburne's first-hand knowledge of Ireland is evident throughout the work, and is shown by his use of 1(*e*), as well as the endeavour to represent bilabial [*v*] by *w* (unless this be referable to scribal usage—*cf.* Lang. 94). *Contending Brothers* indicates 8 points with great consistency, making a notable deliberate attempt to indicate the nature of the Irish substitutions, e.g., in writing "dthe" with presumably [*dð*] for the Irish fan-stop, "fwat" with [*fw*] for the bilabial [*f*], and "vwoud" with [*vw*] for the bilabial [*v*].

We may also remark that, in A, Jonson and the author of *Stukeley* went to considerable trouble to produce realistic Irish-English for stage purposes, although Jonson at any rate had no special knowledge of or interest in Ireland; whereas between 1617 and 1800 there are only two comparable efforts, each written by a man who might be called an "expert" on Ireland—of these *Ireland Preserved* was not meant for acting and *Contending Brothers* never reached the stage.

II. WELSH

In dealing with Welsh pronunciation we have mainly depended on T. H. Parry-Williams's *English Element in Welsh* (London, Cymmrodorion Society, 1923), with occasional reference to Stephen Jones's *Welsh Phonetic Reader* (London, Univ. of London Press, 1926).[6] No work parallel to Hogan's has been done for Welsh-English. The comparative infrequency of Welsh characters after the closing of the theatres makes subdivision of B unnecessary.

1(*a*). [*p*] [*t*] [*k*] for initial [*b*] [*d*] [*g*] (*cf.* Williams 77–78, Jones 11).

"Initial voiced plosives [*b*] [*d*] [*g*] are only slightly voiced" in Welsh, and the English might well have believed that the Welsh unvoiced these sounds completely when speaking English. Welsh speakers may have indulged in occasional provection of English [*b*] [*d*] [*g*], thereby reinforcing the Englishman's notion that the Welsh habitually unvoiced these consonants. Playwrights spell *p*, *t*, *k* or *c*, e.g., "pelly," "Tavy," "Cod," "ket."

A. 9/19.
B. 15/15.
C. 7/7.

1(*b*). [*p*] [*t*] [*k*] for final [*b*] [*d*] [*g*]. (*cf.* Jones 11)

Final [*b*] [*d*] [*g*] are weakly voiced in Welsh. "Goot," for good, is frequent in the plays.

A. 9/19.
B. 8/15.
C. 6/7.

[4] Holinshed, *Chronicles* VI: 4–5, 1808. *Cf.* Lang. 35.

[5] In a recent article on Sir Robert Howard (*Mod. Lang. Rev.* **42**: 314–320, 1947) Miss Florence R. Scott has committed herself to some surprising statements; e.g., that *Bartholomew Fair* shows little knowledge of Irish speech, that *Irish Masque* contains "a dialect which no one ever spoke, but which perhaps by suggesting the King's Scotch, was intended as a compliment to him," and that *Stukeley* was an Irishman and uses dialect in the play. The facts noted above disprove the first and second statements; direct recourse to the play will correct the third.

[6] Cited as "Williams" and "Jones." references are to paragraphs.

1(*c*). [*p*] [*t*] [*k*] for medial [*b*] [*d*] [*g*] (*cf.* Williams, 97–98)

These occur under definite conditions in English words borrowed into Welsh, but occasionally (e.g., *impitans* = impudence) at other times. It seems likely, however, that the unvoicing of these medial consonants (spellings *p*, *t*, *c* or *k*, in the plays) is merely analogical. Such a form as "apout" is almost certainly unrealistic. Examples are "gipes" = jibes, "laty," "acain."

A. 7/19.
B. 5/15.
C. 1/7.

2(*a*). [*s*] for [*ʃ*]. (*cf.* Williams, 86, 109, 123)

In Welsh the *si* substituted for English initial and medial *sh* in loan-words has either the value of [*ʃ*] or of *si* (consonantal) = [*sj*], while [*s*] usually represents English final [*ʃ*]. In the plays *s* is freely substituted for *sh* in all positions. Initially, and medially before a vowel, [*s*] would approximate to [*sj*]; medially before a consonant and finally it would be an accurate representation of Welsh usage.

A. 9/19.
B. 4/15.

2(*b*). [*s*] or [*ʃ*] for [*tʃ*]. (*cf.* Williams, 87, 103, 121)

English initial [*tʃ*] is generally represented in Welsh by *si* = [*ʃ*] or [*sj*], apparently without trace of dental stop. [*tʃ*] is represented medially by *s* before a vowel and *si* before a consonant; finally it is represented by *s*. These values were no doubt evident in the Welsh pronunciation of English, and are indicated in the plays by *s* and *sh*, e.g., by spellings like "shapman" and "surch." [*ʃ*] medially and initially before a consonant would then be an accurate imitation of one of the Welsh substitutions for [*tʃ*]; [*s*] would be accurate only as indicated above, and otherwise would be an approximation to [*sj*].

A. 13/19.
B. 1/15.

2(*c*). [*s*] [*ʃ*] or rarely [*tʃ*] for [*dʒ*]. (*cf.* Williams, 88, 104, 122)

Initial English [*dʒ*] is written *si* in Welsh loan-words, and final usually *s* though occasionally *si*. These are represented in the plays by *sh*, *s*, or (rarely) *ch*, e.g., "sentillman," "shackanapes," "Chesu."

A. 14/19.
B. 6/15.
C. 2/7. } In B and C there is a tendency to confine these indications to "shentleman."

3. Omission of initial [*w*]. (*cf.* Williams, 89)

Earlier loan-words omit consonantal *w* before a rounded vowel, and the combination never occurs in native Welsh words. Before rounded vowels the omission as marked in the plays (e.g., "ood" = wood) was certainly realistic, but it is also found in words, like world and worship, where the ME vowel had certainly been unrounded by 1600; though an occasional spelling such as "oord" = word, in Jonson's *Honour of Wales* (1618) may indicate that Welshmen sometimes retained the ME rounded vowel. If the considerable Welsh community resident in London from Henry VII on had developed an "Anglo-Welsh," they might well have retained the rounded vowel of Early Modern E. On the other hand these may be analogically developed conventional forms, as forms like "imen" = women, and "ense" = wench, must be.

A. 12/19.
B. 3/15.
C. 2/7.

4. [*b*] [*d*] [*g*] for final [*p*] [*t*] [*k*]. (*cf.* Williams, 110, 124)

In Welsh [*p*] [*t*] [*k*] after a vowel are regularly voiced. They are also voiced when final, in English loan-words, if (1) they follow a long vowel in a monosyllable, or (2) a vowel in a word of more than one syllable. Either or both of these, applied in speaking English, may account for the playwrights' sometimes spelling final *b*, *d*, *g*, *as*, e.g., in "trib," "pade," "marg." But since Welsh [*b*] [*d*] [*g*] often seemed voiceless to English ears, these stage voicings are to be explained as realistic only on the assumption that a foreign ear is more appreciative of differences than of the exact nature of substituted sounds, i.e., that when the Welsh substituted their voiced plosive for a final English tenuis, English observers noticed the voiced nature of the sound, but when the same slightly voiced plosives were used for the fully voiced English sounds, it was the

apparent voicelessness which drew attention. But it is perhaps possible that these substitutions are due to irresponsible inversions of 1(*b*) above.

A. 11/19.

5. [*f*] for [*v*]. (*cf.* Williams, 83)

This is puzzling. There appears to be nothing in Welsh speech habits to justify it, frequently though it is indicated in the plays. Possibly the apparent unvoicing of other consonants led to the unvoicing of consonants being taken as a Welsh speech habit, and expressed by the playwrights in spellings like "fice" (= vice), "difersions." It is, however, perhaps more likely that a nodding acquaintance with Welsh spelling, in which *f* = [*v*] and *ff* = [*f*], is responsible.

A. 10/19.
B. 11/15.
C. 3/7.

6. [*s*] for [*z*]. (*cf.* Williams, 110, 124)

[*z*] in loan-words becomes [*s*], and Welshmen would naturally make the substitution in speaking English. Playwrights spell *s*, *ss*, or *c*, e.g., "lyce" (= lies), "sounds" (= zounds).

A. 8/19.
B. 3/15.

In Randolph's *Hey for Honesty* (1629) we find the spellings "hish," "Amashon," "coshen" (= cousin), "disgrash." The first might just possibly be realistic, as final [*s*] for English [*z*] sometimes becomes [*f*] in some dialects of Welsh, but in view of the improbability of [*f*] for medial [*z*] and for final [*s*], the *sh* spellings are probably arbitrary.

7. [*b*] [*d*] [*g*] for medial [*p*] [*t*] [*k*]. (*cf.* Williams, 99)

This sometimes occurs in loan-words; this and the playwrights' spellings may just possibly be due to English medial voicing. Perhaps Welsh speakers adopted an English speech habit which came to be wrongly regarded as a Welsh "barbarism" by those who either lacked the habit themselves or, influenced by spelling, had sharper ears for the foreigner's speech than for their own. Alternatively, for reasons suggested in 4, they may be irresponsible inversions and transpositions of 1(*a*) and (*b*). Playwrights spell, e.g., "taber," "cogscomb," "tiddle-taddle."

A. 7/19.
B. 1/15.

8. [*kn*] for [*n*], e.g., in knock. (*cf.* Williams, 80)

The initial [*k*] before [*n*] is retained in words borrowed before its disappearance from English, and it is always pronounced when the combination occurs in native Welsh words. It seems probable that its presence in easily recognizable loan-words—e.g., *cnoc* = "knock," is very frequent with the stage Welshman—led Welshmen to retain it in their English, and that this was realistically noted by playwrights in spellings like "cannog."

A. 4/19. These indications (between 1599 and *ca.* 1623) that [*kn*] was a foreign pronunciation suggest that the process of losing initial [*k*] and [*g*] before [*n*] was well developed in early seventeenth century English.

9. Omission of initial [*dʒ*] in judge.

"God 'udge me" or "dudge me" may be due to Welshmen dropping the [*dʒ*] which was not native to them instead of substituting [*f*].

A. 5/19.

10. All written "awle," "aull." (*cf.* Williams, 75)

"Awle" is consistently and frequently given to the Welshmen in *Welsh Embassador*, while other characters have "all." We find "aull" in *Honour of Wales* (also "caull" and "tawl")[7]. If these spellings had been intended to carry their ordinary seventeenth century significance they could only indicate [*ɔ:l*]. Further, as a similar vowel existed in Welsh, there was no reason why Welshmen should alter [*ɔ:*]. But if the hypothetical Anglo-Welsh mentioned in 3 did exist, then possibly it took over [*aU*] from a few speakers who retained this diphthong in late fifteenth century English. Jonson (who took *au* and *aw* to represent diphthongs—*cf.* his *English Grammar*, chap. 5)

[7] Only once in *Welsh Embassador* is "awle" given to a non-Welsh character, and then it had appeared in a Welshman's mouth in the preceding line. Similarly, Jonson's "Aulpes" was probably induced by the plethora of "aulls."

and the author of *Welsh Embassador* attempted, it seems, to signify [a*U*] by these spellings.

A. 5/19.

The analysis has provided some instances of more or less probable inaccuracies in the speech of the stage Welshman. A few others deserve notice. Shakespeare has "athversary"; Jonson "toudge" and "welvet." Ruggle's *Club Law* (*ca.* 1600) has "shergeant," *Henry V* "Cheshu," and R. A's *Valiant Welshman* (*ca.* 1610) "Sheshu," none of which seems to have any basis in reality. Neither have "vill," "velsh," and "fere" = where, in *Club Law*, and "tere" = there, "dat" and "tink" in *Club Law* and Beaumont and Fletcher's *Nightwalker* (*ca.* 1616); these look as if they may have been borrowed from the stage Irishman. Such errors, occurring more often than in stage Irish speech, suggest some degree of uncritical acceptance by playwrights and audience of a popular and only partly accurate notion of Welsh-English. Such acceptance of the partly inaccurate (which is often the merely analogical) seems to imply a good deal of conventionality. The figures also tend to show that in A the conventional element is much stronger in the stage Welshman's English than in the stage Irishman's. Twenty-four points (counting subdivisions) are used to indicate stage Irish speech, all of which certainly had some basis in reality; but the Welsh have only 14, of which 6 are more or less doubtfully accurate. The Irish average 8.5 points a play, the Welsh 7. Nine vowel differences are noted for the Irish, but only one, and that in two plays only, for the Welsh. It is also worth remarking that as early as *ca.* 1525, in the jest-book *A C Mery Talys*, a Welshman swears by "cottes blut and his nayle" while Irishmen are not presented as speaking differently from Englishmen.

The greater number of the points indicated by playwrights during A have, nevertheless, a definite relation to reality, though not necessarily an immediate one. Here and there we find spellings which may indicate observations not likely to have been made except as the result of fairly keen audition. Such are: "perger" (= verger) in *Two Maids of Moreclack* (*ca.* 1607) with presumably [*p*] for [*b*], the radical of which [*v*] is the fricative mutation in Welsh; "togedder" and "pedder" = better, in *Honour of Wales*, with [*d*], the radical of which [*ð*] is the fricative mutation (*cf.* Williams, 98); and in the same "madestee" = majesty—burgess and largesse become *bwrdais* and *lardais* in Welsh (*cf.* Williams, 104; also 9 above) But the last two examples are from a work parallel to *Irish Masque* in its serious attempt at accuracy and consistency.

In B only 9 points are indicated with an average occurrence 3.5; in C these figures fall to 6 and 2.5. The certainly inaccurate [*f*] for [*v*] is perpetuated. Although we do not find more than a slight tendency to limit substitutions to particular words, the increasing reliance on few and decreasing indications is a definite sign of increasing conventionality; this is broadly in parallel with the general development of the stage Welshman.

THE GENESIS AND SPEED OF THE TELEGRAPH CODES

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THE unit of measurement for the American and the International Morse Codes is a signal 1/24 of a second in duration; when tape-recorded, the linear length depends upon the speed of the tape-puller.

This basic unit of 1/24″, when doubled, becomes the Morse dash. For the terms dot and dash, "dit" and "dah" have come into usage. I shall adhere to the old nomenclature as more accurate, for "dit" and "dah" infer two different classes of sound when there is but one.

American Morse contains one long dash which Vail did not evaluate in *The Electro-Magnetic Telegraph* pamphlet (1845), but which is worth about 5/24″ (see note 10). Nor did he set a value upon five letter-spaced signals of American Morse which are composed of two, three, and four ultra-rapid dots and are in practice so keyed that the length of the signals are equal, in 24ths of seconds, to the number of dots they contain, inclusive of the intervals between them. The usual dot and dash combinations must always be increased by as many 24ths of a second as there are places in the signal, less one. Inter letter intervals are of 2/24″, and 3/24″ divide words and cipher groups. Lest the fast dots of the letter spaced signals be confounded with combinations of standard Morse dots, the former will be designated by apostrophes and quote-marks. The linear representations of signals in this paper will not necessarily correspond to the duration of the audible signals for typographical reasons.

The 26 signals embodied in the permanent American Morse are those published by Vail in 1845. They are, with their respective signal identities, and indexed in ascending order of length in 24ths of seconds, as follows:

1	2	3	4	5	6	7	8	9
· E	′′ O	′′′ C	′′′′ Y	· · · S	· · – F	· · – – K	· · · – Q	· · · · · P
– T	′′′ R	· · I	· · – A	— — L	· · · D	· · · – W	· · · · X	· · · · J
			– · N			· · · · H	· · · · V	

With the exception of the signals representing Y, Z, and J, previously incorporated as I/Y, S/Z, and G/J, respectively, and the reciprocal metathesis of B and V, which merely swapped signals, American Morse is identical with the 1838 code. The great reform of the code occurred between the appearance of the Caveat Code in 1837 and the 1838 Morse Code, although the signal identities for E, H, K, and N have retained their original form from the earliest time through the changes of International to the present (1949).

Professor Morse had recourse to an unnamed Philadelphia newspaper in 1838 to determine the relative frequencies of the letters of the alphabet. These frequencies, to which I shall refer under the short-title 1838 Press, appear in one of the inventor's notebooks, and are reproduced in the plates of Mr. Edward L. Morse's study of the Morse-Vail controversy, in the March, 1912, *Century Magazine*.[2] This arrangement was:

120	90	80	62	60	44	40	34	30	25	20	17	16	12	8	5	4	2
E	T	AONIS	R	H	D	L	U	MC	F	WY	GP	B	V	K	Q	XJ	Z

The frequencies are here expressed in 100's, for the numbers in Morse's notebook were all round numbers terminating in two and in three zero's. Since as few as 1,000 letters are deemed sufficient to establish an exact distribution, the 1838 press alphabet is quite adequate to its office.[1] Since it was the inventor's intent that the shortest signals be assigned to the letters of greatest frequency and the longer signals to those of lesser frequency, it should be possible to reconstruct the code by assigning the signals from left to right of the 1838

[1] Kasiski established a German frequency expectancy on a 1,060-letter count. Kaeding reached practically the same result with some 62,000,000. (Kasiski, *Die Geheimschriften und die Dechiffrir-Kunst*, Berlin, 1863; Kaeding, *Haeufigkeitswoerterbuch*, Steglitz, 1898.)

[2] Mr. E. L. Morse was not concerned with the technical details of the code, but was primarily interested in giving decent burial to the contentions of the late Alfred Vail's friends and relatives that Vail devised American Morse. See also volume II of Mr. Morse's biography published in 1914.

press alphabet in ascending order of duration. If American Morse be in strict conformity with its generatrix, then, from left to right, the frequencies must diminish in proportion as the signals lengthen. If the frequency numbers be written opposite the letters of American there seem to be many instances of nonconformity:

1	2	3	4	5	6	7	8	9
E 120	O 80	C 30	Y 20	S 80	F 25	K 8	Q 5	P 17
	T 90	R 62	Z 2	M 30	U 34	W 20	X 4	J 4
		I 80	A 80	L 40	D 44	G 17	B 16	
			N 80			H 60	V 12	
120	170	172	182	150	103	105	37	21
120	340	516	728	750	618	735	296	189 = 4292

It is apparent from inspection that there are a good many malassignments. No frequency number should appear to the right that is greater than any frequency number left of it.

A more exact representation of a consistent code would be expressed in this manner:

1	2	3	4	5	6	7	8	9
E 120	O 80	A 80	R 62	U 34	F 25	P 17	Q 5	Z 2
	T 90	S 80	H 60	M 30	C 30	W 20	X 4	J 4
		I 80	D 44	L 40	Y 20	G 17	K 8	
			N 80			B 16	V 12	
120	170	240	246	104	75	70	29	6
120 +	340 +	720 +	984 +	520 +	450 +	490 +	232 +	54 = 3910

The figures at the foot of each column represent, respectively, the total incidence of the signals of that speed and the length of time in their transmissions at 1/24″ per unit dot. The code evolved by Professor Morse, exclusive of all intra-letter and group intervals, is such that 4,292/24 seconds are requisite for transmitting a telegram of 1,060 letters and 212 words. It is necessary to figure in the length of time for the necessary intervals, as follows: of the 212 groups or words, 211 of them are separated by intervals of 3/24″ per each, or 633/24″ in all. Of the remainder of the letters, 848 must be separated from the next letter by an interval of 2/24″, or, in all, 1,696/24″. The total time consumed is therefore 2,329/24″ for these pauses, plus 4,292/24″ for signals, or 6,621/24″. By this somewhat tedious process it is disclosed that American Morse has a theoretical speed of 46.08 words per minute.

So much for American Morse as it is. But if the identical process be applied to American Morse as it ought to have been, our total signal-transmission time is reduced to 3,910/24 seconds, plus the same intervals of 2,329/24″ for a total time of 6,239/24″. For this figure, the code-speed increases from 46.08 to 49.33 words per minute, or a gain of better than .07.

It will be noted that there are in American Morse 12 malassigned signals, to wit: A, S, R, H, D, U, C, Y, B, K, P, and Z, whose aggregate occurrences in 1,060 letters of text are 453, or about .43 of the total. That almost half the letters of the alphabet be malassigned, that almost half of the 1,060 signals of the transmission be out of proportion with the letters they represent, and yet the cumulative retarding effect on code speed is but .07, seems at first unreasonable if not downright incredible.

On second thought, however, it may be recalled that a letter or a signal may be malassigned in two different ways: either a high frequency letter is represented by a signal too long for its incidence, or a low frequency letter is represented by a signal too rapid for its letter. And in the last analysis, every malassignment is dual and there is a compensatory effect. For, to take an extreme example, if the letter E is assigned to a signal of 9/24″, either Z or J is going to have the 1/24″ signal which E should have, and the speed drop is not represented by the ratio 1,080/24″ : 120/24″, but 1,080/24″—2/24″ *or* 4/24″ : 120/24″. The malassignments are *not* so extreme, but do not begin to occur until the third group and are therefore bunched in the middle and towards the foot of the frequency. Six letters are assigned signals too short, and 6 signals too long. The code speed reduction is not .43 of the total occurrences of the 12 letters, but scarcely 1/6 of that.

No matter how many malassignments there may be, or their character, a slow code cannot be constructed at all out of these signals. The slowest possible code is obtained by reversing the 1838 press alphabet and assigning signals to the letters from left to right in the usual ascending series by signal duration.

1	2	3	4	5	6	7	8	9
Z	JX	QKV	BPGY	WFC	MUL	DHRS	INOA	TE
2	8	25	70	75	104	246	320	210
2	16	75	280	375	624	1722	2560	1890 = 7544

Adding the constant interval value of 2329/24″, a total of only 9873/24″ is obtained, equivalent to 31.00 words per minute. The fastest possible code, already mentioned *supra*, was but 49.33; American Morse, 46.08.

A device such as a signal reversal might well prove to be worth while; the present level of potential code speed in transmission is far too great for the practical limit of 25 words per minute which is about the best that may be done in manual transcription. Most telegraphers enjoy transmitting at high speed and with complete signal reversal would be able to do so without regard to outstripping the receiver by any great margin.

Another factor which tends to equalize the slowest and fastest code speeds is the constant value that must always be allowed for letter and word groups. The signals themselves are composed of elements which are, in turn, separated by intervals of 1/24″. All the silent intervals in the 1,060-letter Morse message at hand add up to 3,608/24 seconds, and since the entire transmission time is only 6,621/24″, then about .55 of the whole transmission time is swallowed up in periods of silence.

Aside from reducing the intervals, there is nothing that may be done to utilize this period of non-productivity. The communication of all intelligence, whether by signal, syllable, letter, character, ideograph, or what-have-you, is postulated upon symbol differentiation in series. A telegraphic message of 1,060 letters from which all intervals have been eliminated might be represented as 3,013/24″ of signal time; more accurately, it is a continuous signal of 2.9 minutes duration, all separate components having lost their individuality. 3,013/24″ might as well stand for a Morse E over 3,000 times the prescribed length; or Morse T's or L's more than 1,500 and 600 times their usual lengths. Silent periods between components or letters are merely the symbol-differentiations. Any other differentiation would do just as well. The simplest of all differences is silence, or measured quantities of nothing, if a paradox is permissible. Intelligibility of signal will be the same, however, if the intervals be represented by a brass band playing "Columbia, Gem of the Ocean."

That more than one half of the transmission time be composed of silence appears at first excessive. A halving of the base-value of 1/24″ for the intervals only would effect a considerable economy of time and augment the code speed. But any reduction of the intervals by a constant factor infers that a similar degree of control is also applicable to the code signals and if rapidity alone be the objective, let the signals too be halved, raising American Morse from about 46 to 92 words per minute. This objective being gained, reexamination of the ratio between total signal duration and total silence shows the same old .45–.55 relationship. If code-speed be the real objective, and if 46 or 92 or 184 words per minute serve our purpose, the signal-silence relationship is an extraneous feature. And even were it not, and even if one degree of control were applicable to the length of the silences and another to that of the signals, the electrical efficiency of the metallic circuit requires short signals and long intervals. In metallic circuits of any considerable length, and to a lesser degree in ground return lines, the two conductors act like a great capacitor, or condenser, storing the current as though between positive and negative plates and discharging it independent of the will of the telegrapher. To counteract this capacitance, inductances, or loading coils, are cut into the circuit at fixed distances. Up to a certain point, not only the length of the circuit, but the length of time during which current flows, are factors determining how much capacitance there will be and what inductance is required to bring the circuit into that state of resonance or balance necessary for telegraphic communication.[3] And in general, the shorter the signal and the greater the interval between signals, the better the signal and the fewer the obstacles set up electrical impedances, residual magnetism, and the like.

Maximum code-speed will never be attained, regardless of technological advance in electrical communication methods, until such time as all 26 letter signals be represented by a signal short

[3] The early submarine cables were unable to transmit more than two Morse dots per second until current reversal was successfully demonstrated. In such circuits it is more accurate to refer to impedance rather than resistance, and the term reactance is that part of the impedance of the current flow attributable to an improper balancing of the capacitance and inductance of the circuit.

signal. This is impossible on single-frequency telegraph circuits, but a coaxial cable for 26 frequencies would be as effective as 26 complete metallic circuits. Let Frequency x effect electrical connection with the letter A of a keyboard, Frequency $x + 1$, with B; $x + 2$, C; $x + 3$, D, and so forth. Then the speed of *direct* communication will be limited only by the ability of the printer to take down the letters from the relay, or that of the operator to work the keyboard. There are all sorts of gadgets, however, that will transmit and receive specially prepared messages much faster than the hypothetical direct communication keyboard above described. These messages are not only prepared at a very slow speed but are retranscribed at a comparably slow rate, and might be considered *indirect* communication. The practical upper limits of speed will always be limited by the ability of some human being to operate a keyboard, until such time as electrical connection be made direct with the receiver's central nervous system.

The American Morse Code was a typically American device, designed by an American for a telegraph system invented by an American, and most suited for communication in American English. It was .93 as rapid as the very fastest code that could be devised for use in American English and it was about .80 efficient in that, at an average of 46 words per minute, its speed lay 8/10 of the way between 31 words per minute and 49 words per minute delimiting, respectively, the lower and upper limits of speed for any code constructed with the American signals and the 1838 press distribution.

The International Morse Code, originally designated as the Continental Telegraph Code, represented the European telegraphers' reaction to a code which might possess all the desirable qualities for communication in English but few for other languages. The 5 letter-spaced signals were anathema to European operators, and they also had logical objections to the inclusion of the long dash for L, and the 5 dots representing P. They did not care for Morse's somewhat haphazard system for numerals. Morse's telegraph code, worked out over a period of years in the United States and Canada, was bequeathed *ipso facto* and whole, like Minerva full blown from the brain of Jove, to a Europe which had hitherto known it only by hearsay if at all, and which had in the past decade already built up a telegraph tradition of its own. France had its miniature semaphore in the Chappe aerial telegraph tradition; the German states their dials; England used dials and needles. Many different types of telegraph were used in every country. And the change-over was a painful one.

It was rendered no less painful by the fact that in all countries except England, telegraphy was the monopoly of Government and its operators were oftener than not appointed from the civil service list—the partially disabled war veteran, the ward of the state, the sub prefect's son-in-law, and the more obscure bastardy of the reigning house, all these and more made stranger bedfellows than any combinations of contemporary politics. The change-over to Morse was effected on the international circuits by 1850. Spain, central and southern Italy, and the Balkan States were hold-outs for at least another five years.

By no later than August of 1855, the American Morse Code was just an unpleasant memory in Europe. So much, at all events, is to be inferred from examination of Miège and Ungérer's *Vade-Mecum Pratique de Télégraphie Electrique,* the quasi official manual of the French Telegraph Administration. No reference whatsoever appears in the *Vade-Mecum* to any code other than the Continental Morse. Nor is there to be found any inference as to the date of its adoption.

From other printed sources, however, it is apparent that the change was effected after August of 1852. This was the publication date of the Abbé Moigno's history entitled *Traité de Télégraphie Electrique,* which is as innocent of any reference to the Continental Code, as is the *Vade-Mecum* to anything else.

The Continental Code did away with the 5 letter-spaced signals, and the American Morse 5-unit long dash for L. The 5 standard Morse dots for P reappear in the Continental numeral-sequence as the number 5. To obtain 7 signals from the 2-element 4-place code, the revisor or revisors need but select them from among the 11 signals not used in American Morse for letter-signals. These were, in the order of length:

8	9	10	11
– – –	· – – ·	– · – –	[– – – –]
	– – · ·	– – · –	
	– · · –	· – – –	
	[· · – –]	[– – – ·]	
	[· – · –]		

Assignments were made from these signals direct only to the letters O, P, Y, and Z; the remaining 3 letters, i.e., C, L, and R, received the former American Morse signals for J, X, and F; F was

then handed the former American Q signal, the net result being that the following letters were up for reassignment: O, P, Z, X, Y, Q, and J, designated as follows:

8	9	10	11
– – – (O)	· – – · (P)	– · – – (Y)	[– – – – (CH)]
	– – · – (Z)	– – · – (Q)	
	– · · – (X)	· – – – (J)	
	[· · – – (Ü)]	[– – – · (Ö)]	
	[· – · – (Ä)]		

Exclusive of accented letters and of special combinations, the Continental signal assignments for the alphabet were:

1	2	3	4	5	6	7	8	9	10
E ·	T –	I · ·	A · –	S · · ·	U · · –	K – · –	F · · · ·	C – · – ·	Q – – · –
			N – ·	M – – –	D – · ·	G – – ·	L · – · ·	P · – – ·	Y – · – –
					R · – ·	W · – –	B – · · ·	Z – – · ·	J · – – –
						H · · · ·	V · · · –	X – · · –	
							O – – –		

Now, let this sequence be rewritten on a single line and compared with that of American Morse:

	1	2	3	4	5	6	7	8	9	10
American	E	TO	CIR	YANZ	LSM	UFD	WGHK	BXQV	PJ	– – –
Continental	E	T	I	AN	SM	URD	WGHK	BFLVO	CPXZ	QJY

There are 16 coincidences between the two codes, 10 letters being represented by different signals. A quick visual comparison of Continental's sequence reveals that it was clearly not based upon any major language's frequency distribution, and that, if it bears any particular resemblance to the 1838 American press frequency, it does so only because American Morse was based thereon, however erratically. Further inspection of the sequence as a whole, and of the several instances of signal transference, furnishes the strongest kind of circumstantial evidence that the principle of phonological analogy guided the code-revisors in the reassignment of the signals.

The following are the cases in point: C = – · – ·, K = – · –; L = · – · ·, R = · – ·; the original assymetry of American B = – · · ·, V = · · · – has remained intact. These take care of certain velars, liquids, and labials; others, and the dentals, fricatives, and spirants, gutturals, may not be matched for lack of sufficient like signals.

Were these signal pairs devised to facilitate rapid memorization of the Continental Morse, the code revisors were hardly justified; the memorization of the letter signals even of American Morse is but a matter of a few hours. It is the ability to coordinate the hand, the eye, the ear, and the mind that distinguishes a good operator from a mediocre one. While the phonetic characteristics of pairs of consonants may, for a very brief span, be of comfort to a student telegrapher, the signals – · – and – · – ·, · – · · and · – ·, shortly acquire a wholly different character in the telegrapher's ear, each possessing a definite and unmistakable rhythm of its own, and these rhythmical signals sound no more alike to the ear than do K and C, or L and R, look alike to the eye.

The measure of potential speed of Continental Morse is carried out on the same lines as that of American Morse. It would, nevertheless, be unreasonable to judge Continental's theoretical rapidity by the same frequency distribution which applied to American. Another yardstick must be fashioned, engine-divided and reindexed to measure rapidity in terms of the frequencies of letters not only for English but also for as many other principal European languages as may be available for computation. Ohaver (*Cryptogram Solving*, 1933) has assembled the frequency distributions and expectancies from various sources for English, German, French, Italian, Spanish, and Portuguese. Utilizing this data, which I include in the appendix hereto, the following arithmetic mean is derived:

142	100	79	76	75	69	67	58	46	44	42	31	30	24	23	17	14	12	7	5	4	3	2
E	A	O	I	N	S	R	T	L	D	U	C	M	H	P	G	V	FB	Q	WZ	Y	J	KX

The Continental Mean is not a reality. It is a mere statistical generalization, subject to the variation of language and to experiential error in every stage of its construction. It overstresses the Romance languages while simultaneously disregarding the Scandinavian and Slavic. On the other hand, there is no doubt that this Continental Mean adequately represents the linguistic character of the large majority of Western European

peoples in respect to population, military and economic power, and telegraph facilities.

The speed of Continental Code with the Continental Mean frequency is based on a transmission of 989 letters [4] and is a shade better than 40 words per minute. When the speed of the American Morse is computed on this same basis, it is found that 48.2 words per minute are transmitted. This phenomenon is not so much accidental as incidental and may be attributed to two factors, viz.: (1) American Morse's superior speed in average signal duration, and (2) the higher incidence in the Continental Mean of the same letters in American Press 1838. For example, there are 142 E's in the Continental Mean per 989 text letters, but in the American press frequency, there were but 120 in 1,060 letters. For equal speed, there should be more like 152 E's in the 1838 frequency, and an exact proportion among the other letters.

Since the upper limit of transcription speed lies around 125 letters per minute, this is the maximum speed that may be had on manual circuits. While, theoretically, transmission speed is reduced by a lengthening of the intervals between letters and words without a corresponding lengthening of either signal elements or the spaces between them, in practice elements and intervals are reduced, though not uniformly. It is not that the receiving telegrapher cannot identify the incoming signals; he simply cannot write down the letters corresponding to them. The letter which is heard most often in every language but the Portuguese and which is represented by a single short sound, is practically certain of at least 110 occurrences in 1,000 letters and may run as high as 150. Three occurrences in 5 letters is by no means uncommon. For 3 E's alone, the transmission time will be 3/24″ for the actual signals, and 4/24″ for the inter-letter pauses. E is a letter ordinarily requiring 4 pencil strokes separated, like telegraphic signal elements, by equal intervals between strokes. If the unit of measurement per stroke be equal to that of the Morse dot, the transcription time for 3 E's, including one interval after the final stroke and before the commencement of the first stroke of the following letter, will be $8/24'' + 8/24'' + 7/24'' = 23/24''$.

The average reaction-time to an auditory stimulus lies in the neighborhood of 0.153 seconds.[5] Since the decimal equivalents of 2/24″ and 3/24″ are but 0.083″ and 0.125″ respectively, it is apparent that the time-lapse between any given signal-stimulus and the following signal-stimulus is on the average inadequate even for recognition of the signal, much less for its transference to a message-form. Furthermore, the 2/24″ inter-letter intervals for all Morse signals of fewer than 4 places, with the exception of the signal − − − = O, are not part of the reaction-time at all, but are integral parts of the signals themselves. Consider, that the signal · · and no interval, or · · plus 1/24″, need not be the letter I at all. Only after the lapse of 2/24″ or more is it certain that your · · will not after all turn out to be · · ·, or · · · ·, or · · −, or · · − ·, or · · · −. The signals representing A, D, E, G, I, K, M, N, R, S, T, and W must be waited out; all others, including O, are recognizable instantly the signal ends, for there are no 5-place letter-signals in Continental, and O is complete because there are no combinations such as − − − · or − − − −.[6]

So no telegrapher can take down letters as fast as they come at service speeds. Recognition of the first signal is not complete, generally, until the second signal is over; transcription of the first signal is barely complete until the third signal is over. If a telegrapher could do only one thing at a time, he would be able to write only the first, fourth, seventh . . . etc. signals, or the second, fifth, eighth . . . etc. The fact is, he can and does do two things simultaneously; the transcription of a recognized signal is largely a conditioned reaction requiring a minimum of intellection; he listens while he writes. He could not do his work otherwise. His normal position is from two to four letters behind the telegraph key, and in the long run, the times he starts falling back too far are balanced by those when he can work within say a single letter of the transmission and when they do not balance, that's what the break and the $\overline{\text{IMI}}$ are for.

[4] When Ohaver's 10,000-letter counts were reduced to 3 places, 11 letters were dropped instead of being expressed in decimals.

[5] William Berry on psychology in *An orientation in science*, by C. W. Watkeys *et al.*, ed., 448, Univ. of Rochester, 1938. Professor Berry computed upper and lower limits of sensory stimuli reaction times from the work of other investigators. Auditory upper limit, 0.185″; lower limit, 0.120″.

[6] This applies only to the 26 letters of English. In Europe, − − − · is O with any written accent; the Spaniards asked for − − − − for their letter CH, and for − − · − − = $\tilde{\text{N}}$.

Increasing amounts of traffic in cipher furnish relief from an unexpected quarter. Although a non-telegrapher is likely to feel that meaningless strings of letters in groups of 5 letters would be more difficult to take down than intelligible and familiar words, the exact opposite is true. In plain text, the operator, against his own will, is often influenced to anticipate letters, syllables, and even whole words, long before they come to him, and more often than not the involuntary and irrepressible speculation is incorrect and he is thrown off stride by unforeseen combinations.

Of all cryptograms, those encoded in polyalphabetic substitution cipher are the easiest to transcribe, and the greater the number of cipher alphabets used, the greater the ease of transcription. The principal obstacle in plain text, and in transposition ciphers (in which the same text letters appear but in a different order than in the plain text), is the ratio of the short-signal high-frequency letters to the long-signal low-frequency letters. In the Continental Mean frequency, for instance, the ratio of E's to X's is 71 to 1, and that of their respective signal lengths is 1 to 9. Exclusive of intervals, a 4-stroke letter is transmitted in 1 unit of time 71 times for every single occurrence of a 2-stroke letter transmitted in 9 units of time.

In the better types of polyalphabetic substitution, this vast discrepancy is abolished. In 1,000 letters of text, the number of each letter of the alphabet will be practically the same. There will be 38 E's, 39 M's, 37 L's, 38 U's, and so forth; a frequency-count will show neither crests nor troughs. The probability, at any given point in the cryptogram, that the next letter will be E, is 1/26, while in ordinary text it would be 142/989; EE's cipher probability is 1/676; in plain text it is 42/1,000.

There is a considerable diminution of operating speed in the transmission of polyalphabetic substitution. Owing to the equal incidence of all letters of the alphabet, 32 words per minute is the speed of the International Morse code contrasted with its plain text speed of 40. American Morse falls off from 46 words to approximately 38.5. The speed losses for substitution cipher are uniform regardless of the language of the original plain text. For the American Morse Code, used with the 1838 Press, the speed loss for polyalphabetic substitution cipher in cycles of 26 random-mixed cipher alphabets, the percentage is about .16; International Morse with the Continental Mean distribution loses about .20 of its plain text rapidity. It is, then, clear that no matter what the distribution and incidence of the letters of the plain text were, the cipher text will show a practically equal incidence of all letters, and the faster the plain text, the greater the percentage of loss of the cryptogram. The greater the loss in speed, the greater is the degree of signal security. With a well constructed cipher of this description, solution is virtually impossible. All of the proverbial monkeys of the New World and the Old, with every typewriter in Christendom and Pagany, will have no more success in solving it by chance than will cryptanalysts by design.

Other developments have tended to diminish the importance of frequency balanced telegraphic signal codes. The effective operation of automatic transmitters is largely dependent upon metallic conductors and alternating currents. If the telegraph key be turned on its side, and the left and right contacts be coupled with the positive and negative terminals of the battery, then the Morse dot may be transmitted on one conductor and the dash on the other, by impulses of any convenient duration. Furthermore, when such a circuit be automatized, the interval between unlike signal elements is practically eliminated, and the International Code so shortened that instead of containing letter signals ranging from one to ten units in duration, it is composed of signals ranging from but one to seven units. The great speed of the automatic transmitters is partially to be explained by these considerations. Theoretically tremendous speeds are attainable, and in practice over 50 words per minute, by utilizing alternating currents of fixed frequencies and feeding prepunched tapes, drawn by a synchronized tape puller, into the transmitter at a rate such that every perforation corresponds to a positive or negative pulsation, which may, by such coincidence, be amplified into the appropriate signal impulse, or suddenly interrupted.

These, along with continuous and pulsating D.C. circuits, are known as "closed circuit" lines. Some sort of carrier wave is on the line continuously. There is a certain advantage in this type of circuit which open circuits do not possess, which is of some importance for very long-distance telegraphy with few or no repeaters between the communicating offices. For since the electro-magnetic wave is propagated at no more than 186,000 miles per second, on open circuit offices 1,000 miles apart 1/93 part of a second is the shortest signal that will be transmitted, for in

1/186″ the current would just have reached its destination; for any current to flow in the receiving instrument, that current must return whence it came, either by metallic conductor or by ground return. If a telegraph station lay 186,000 miles out in space, not only would the minimum requirement for transmission be 2 full seconds per unit dot, but no signal less than 2 full seconds in length would close the circuit and cause any signal to be sounded at all. Remove this office to a distance of one parsec in space, and no signal shorter than 6 1/2 years will suffice to represent a single Morse dot.[7]

On the contrary, on closed-circuit systems, messages may be transmitted regardless of distance or intermediate stages of relay at any speed the telegrapher may desire. While the time consumed by a signal in recording itself at destination remains twice that of a light ray, when it does get there it need not last for any 2 seconds or a million years, but is faithfully recorded in 1/24 or 1/1,000,000 of a second no matter how far it travelled or how long it took. The eclipse of a binary star by its darkling satellite may take centuries of time to reach the earth, but is faithfully reproduced in the same period.

By Kelvin's Law, speed is directly proportional to conductivity and inversely to resistance. Current output on an A.C. circuit in any given cycle should be close to zero, no dot following a dot, no dash following a dash. Radiotelegraphy may profitably utilize selective full wave modulation, filtering off or converting negative potential by rectification, because the operating frequencies range from tens of thousands to hundreds of millions of cycles per second. Telegraphy, whose audio frequencies run from say 5 to 100 cycles depending upon circuit characteristics and loading, if any, should utilize both sides of the sine curve for actual signal record. In 1923, the Chief Signal Officer[8] of the U. S. Army purposed to rewrite the Continental Cable Code to balance cable circuits and simultaneously furnish speeds of 450 words per minute on 60 cycles. The speed of this code, as I calculate it, at 60 cycles, with plain text of the Continental Mean distribution, stands at 396 words, and for cipher, 330. The so-called Squier Alphabet, a sample of which is vouchsafed, proves to be the International Morse Code with negative potential filtered out or converted. Modulating both positive and negative impulses for either dot or dash, the alphabet from A to Z may be transmitted in 41 cycles hence 450 plus words per minute, only by running the letters together without the 1/2-cycle intervals which may be omitted within letter-signals but not between letters themselves, and, of course, the 450-word speed would apply only to cipher—if it were not for the missing intervals that turn the code to gibberish. The same principle, which General Squier would also apply to radiotelegraph circuits, would not seem to reduce the power requirements as suggested and a harmonic of 60 cycles must be selected inasmuch as the radio frequencies do not go much below 15,000 alternations per second and no amount of kilowattage would cause an antenna to radiate on a wave length such as 500,000 meters. Differential modulation of this character would indeed balance up the circuit, although the greater number of Morse dots to dashes within the letter signals (44 to 38) will always assure, in the long run, that one conductor is going to do more work than the other, but the discrepancy is not great and well within the tolerances. In the present cable code, one conductor habitually transmitting signals of one sign and the other conductor its opposite, the ratio, in polyalphabetic substitution cipher will stand at exactly 38 to 44, and either conductor being utilized for both signs by modulated signals for dots and dashes above *and* below the zero point, the imbalance should become even less.

General Squier's predecessor, Gen. Albert J. Myer, first C.S.O., also looked askance at the American Morse Code, experimented disastrously with dial induction machines 1861–1863, and decreed after the war that his own General Service Code of 2 elements and 4 places be used on all Signal Corps circuits—in 1880, 5,000 miles of them, mostly in Indian Territory. In 1886 his successor, General Hazen, tried out Continental for three years; then American Morse, to 1896, when the Corps gave up and went back to the General Service Code again. In 1912, when the 2nd Radiotelegraph Conference proclaimed Continental the standard wireless code, the Signal Corps followed suit.

[7] I am aware that the speed of electricity under ordinary conditions in metallic conductors is not that of light nor anywhere near it, and that it runs as slowly as 10,000 miles per second and ranges on up towards 186,000 in accordance with electrical characteristics of the circuit. I utilize the speed of light as a philosophical abstraction to show signal lengths under the very best conditions possible.

[8] Gen. Albert O. Squier, Expediting electrical communications, in *Popular research narratives* II: 34–37, Baltimore, Williams & Wilkins, 1926.

While this heresy may not have been very contagious, certainly no one may say that it was the whim of a moment. And yet, it was a whim just the same. The first C.S.O., who had been badly worsted in a service feud with the U. S. Military Telegraph Corps in 1863 over who was going to work the flying telegraph, held a perhaps unreasonable prejudice against everything related to commercial telegraphy, including its service code. While some of his criticisms were extremely apt ones, the Chief made himself look foolish by his continued insistence that he could make "simple codes" of two and three "distinct sounds" without considering that that was precisely the basis upon which the American and Continental Codes were predicated already. Short sounds and shorter sounds, or long sounds and longer ones, are the working basis for ordinary Morse telegraphs with battery sounders. You may alter the length of the somewhat unmusical bleat of a telegraph buzzer, but you can not alter its character any more than you can teach a dog to mew or a canary to roar like the king of beasts.

These small scale rebellions against the sanctity of the Morse telegraphic codes are the only ones ever instituted, to the writer's knowledge, and are of no particular importance. On the whole, telegraphers both military and civilian have been willing to accept first the American, then the Continental Morse Codes, as phenomena of nature to be conformed to and not to be questioned. No detailed analysis of either has been made with the exception of the early studies of the inventor himself which resulted in the American Code, and these studies are fragmentary and unpublishable as anything but a curiosity. Practically all writers, both lay and technical, remark that the short signals represent high-frequency letters and vice versa, but none go much beyond the example of E = .

Nor is there any reason why they should. It is hard to say to what particular field of the arts or sciences that signal code development pertains. It is a matter somewhat related to the general art of cryptology,[9] yet it is not wholly divorced from electrical engineering nor from general philology. Its analysis is beyond the province of cryptanalysis and cryptography; it relates to engineering only in so far as its adaptability to electrical circuits is concerned; while the scholar and the philologian, untutored in the signal art, are prone to disregard the matter because it appears, at first glance, analogous to counting the number of *the*'s in Shakespeare.

For several reasons, many of the conclusions arrived at in the present paper will be found at variance with those to be seen in standard works of reference on telegraphy and the radiotelegraph. Sometimes the discrepancies are explainable with reference to the point of departure. Most encyclopaedists describe the Continental Morse, for example, as it is used today for radiotelegraphy; for this use, the Morse dash is computed as a 3/24″ signal. The longer signal not only illuminates the dot by contrast, but is designed to cut through static and interference. The American Code is the same as it was in 1845 and I measure it by the criteria laid down in the 1845 telegraph pamphlet, although I am aware that Morse, at least, expected no such speeds as may be had by following his instructions, for he told the French Telegraph Superintendent in the autumn of 1845 that his lines would pass 60 signals a minute (12 words) and that with improvements to come would pass 150 (30 words).

Many writers are not averse to venturing an educated guess as to interval-duration in all positions, value of American L, spaced letter values, and the like.[10] That many of these writers are, or were, practical telegraphers is no warranty of a correct answer. Not even a professional operator is qualified to estimate correctly intervals differing by fractions so small as the twenty-fourth part of a second, while the frequent assertion that code speeds range from 20 to 40 words per minute, more or less, while unquestionable, imparts little information about average transmission speeds, although the values and the letter-frequencies are all available for the computation.

In short, I consider that, given the values for components and intervals, it is both feasible and practical to assert that under average conditions,

[9] A coined word embracing both cryptography and cryptanalysis and in general use among signal intelligence officers, brevity and security code compliers, and those who work with code and cipher.

[10] My own assignment of L to the fifth group is in accordance with L's position in the 1838 Press distribution. As to spaced letters, I am unable to cite authority for my own rule that their values are equal in unit dots to the sum of their short-dots, hence " (0) = 2/24″, "" (Y) = 4/24″, etc. A railway telegrapher cannot tell you the values and it is impossible to estimate them by listening to them or sending them yourself. The scientific way of determining these values would be to bring an experienced telegrapher to a psychology laboratory and hitch him up to a chronoscope, but it would be unscientific to apply a scientific measurement to one class of signal and a theoretical one to the other classes.

the manual transmission speed will lie in the neighborhood of x words, subject to certain reductions of a uniform nature peculiar to the individual and/or the circuit he works.

This is no blanket-indictment of Authority, but an explanation of why I have so little recourse to standard works. The fact is that the historical aspects of the Morse Codes have been uniformly disregarded and the signal assignments have been accepted without question as something beyond the comprehension of mere mortals, whereas of course they are not, and · = E not because God made it that way, or because it is a first principle of nature, but because S. F. P. Morse said it was and because everybody accepted it as such. The notion that both the codes are frequency based is both right and wrong, for Morse made 12 errors out of 26 on the American assignments and had nothing to do at all with the International revision, which is frequency based only in the instance of signal identities in International coinciding with signal identities of American which were among the initial 14 correctly grouped signals.

With no malicious intent, and with due allowance made for the superiority of hindsight over foresight, I feel that Morse might have done rather better in his assignments, since he had at least seven years to think them over before Vail published them; the Philadelphia Press distribution furnished all the answers and even at that, Morse could score only a miserable .54 correct assignments. Instead of contending for the credit of authoring such a mediocrity, the principals and their advocates should be disowning it and attributing it to the opposing faction. It works, all right, but it is none the less a product of careless and confused thinking.

APPENDIX

Ascending Series of Signal Values for Telegraph Codes

	1	2	3	4	5	6	7	8	9	10	11
Morse 1838:	E	TO	IYRC	AN	SZML	UFD	HGJWK	BVXQ	P	–	–
Morse 1845:	E	TO	IRC	ANYC	SML	UFD	HGWK	BVXQ	PJ	–	–
Bain 1846:	E	I	O	ABU	CY	SD	HPRL	GJZ	QKWXMN	TFV	–
Continental:	E	T	I	AN	SM	URD	HGWK	BVFLO	PCZX	QJY	–
Gen. Serv.:	I	T	N	EO	YA	URC	HSL	QWD	PBGJMK	FXV	Z

Typical English Distribution Patterns

	120	90			80			62	60	44	40	34	30	25	20	17	16	12	8	5	4	2	
Press 1838*:	E	T	A	O	N	I	S	R	H	D	L	U	M	C	F	W	Y	G	P	B	V	K	Q	X	J	Z
	123	95	80	79	71	71	65	60	51	40	36	32	31	22	20	18	16	9	5	2	2	1	.9		
Gaines 1942:	E	T	A	O	N	I	S	R	H	L	D	C	U	P	F	M	W	Y	B	G	V	K	Q	X	J	Z
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Military 1916:	E	O	A	N	I	R	S	T	D	L	H	U	C	M	P	Y	F	G	W	B	V	K	X	J	Q	Z
	120	90	83	76		74	72	58	40	36	33		30	27	25	21	18	14	13	11	5	3	2	1		
Telegraphic:	E	T	R	I	N	O	A	S	D	L	C	H	F	U	P	M	Y	G	W	V	B	X	K	Q	J	Z
	130	90	82	78	72	67	66	64	58	41	36	29	28	27	26	21	15	14	13	12	10	4	3	2	1	.9
Ohaver 1933:	E	T	O	A	N	I	R	S	H	D	L	C	F	U	M	P	Y	W	G	B	V	K	X	J	Q	Z
	130	92	79	76	75	74	74	61	42	36	34	31	28	27	26	25	19	16		15	10	5	3	2	1	
Govt-Telegr 1938:	E	T	N	R	O	A	I	S	D	L	H	C	F	P	U	M	Y	G	W	V	B	X	Q	K	J	Z

* Press 1838 based on 1060 letters; all others on 1,000 letters.

Typical European Distribution Patterns

German:	E	N	I	R	S	A	D	T	U	G	H	O	L	B	M	C	P	W	Z	K	V	P	(J	Q	X	Y)
French:	E	A	I	S	T	N	R	U	L	O	D	M	P	C	V	Q	G	B	F	J	H	Z	X	Y	(K | W)
Italian:	E	A	I	O	N	L	R	T	S	C	D	P	U	M	V	G	H	F	B	Q	Z	J	(X	K	W	Y)
Spanish:	E	A	U	S	N	I	R	L	D	U	C	T	M	P	B	H	Q	G	V	Y	J	F	Z	X	(K | W)
Portuguese:	A	E	O	R	S	I	N	D	M	T	U	C	L	P	Q	V	F	G	H	B	J	Z	X	(K	Y	W)
	142	100	79	76	75	69	67	58	46	44	42	31	30	24	23	17	14	12		7	5	5	4	3	2	
** Continental Mean:	E	A	O	I	N	S	R	T	L	D	U	C	M	H	P	G	V	F	B	Q	W	Z	Y	J	K	X

** Continental Mean based on 989 letters. References: Parker Hitt, "Manual for Solt'n of Mil. Ciphers" (1916); *Encyc. Brit.*; H. F. Gaines, "Elementary Cryptanalysis" (1942); Meaker Freq. Chart; Ohaver, "Cryptogram Solving" (1933).

HISTORICAL TABLE OF SIGNAL ASSIGNMENTS, 1837–1860

	Morse					
	1837	1838	1844	1848	BAIN	MORSE
·	E	E	E	E	E	I
··	R	O	O	–	–	–
–	T	T	T	T	I	T
···	G/J	C	C	–	–	–
·–	C	R	R	–	–	–
···	B	–	Y	–	–	–
····	D	–	Z	–	–	–
·–	F	–	–	–	–	–
··	O	I/Y	I	I	O	N
·–	I/Y	A	A	A	A	E
–·	N	N	N	N	B/U	O
···	A	S/Z	S	S	C	Y
––	X	M	M	M	Y	A
———	L	L	L	–	–	–
·–·	S/Z	F	F	R	–	C
·–·	W	U	U	U	D	U
–··	M	D	D	D	S	R
–·–	K	K	K	K	P	S
·––	U	W	W	W	H	H
––·	T	G/J	G	G	R	L
····	H	H	H	H	L	–
··–·	Q	Q	Q	F	–	W
·––·	–	X	X	L	G	Q
–···	–	V	B	B	–	–
···–	–	B	V	V	J	–
–––	?	(5)	(5)	O	Z	D
–·–·	–	–	J	C	–	K
·––·	–	(1)	(1)	P	K/Q	M
––··	–	(7)	(7)	Z	W	G
–··–	–	(9)	(9)	X	X	B
·····	P	P	P	(5)	–	–
·–·–	–	–	–	(Å)	M	P
·–––	–	–	–	(Ü)	N	J
–·––	–	–	–	Y	T	X
––·–	–	–	–	Q	–	–
·–––	–	–	–	J	F	V
––––·	–	–	–	(Ö)	V	F
––––	–	–	–	CH	–	Z

CODE-SPEEDS FOR PLAIN TEXT AND SUBSTITUTION CIPHER IN PRESS 1838 AND CONTINENTAL MEAN, AS INDICATED

Code	Words Per Minute		Substitution Cipher		Cipher Loss
American 1845	46 (1838 Press)	.13	38.5	.17	.16
International 1855	40 (Cont. Mean)		32		.20
Cable, Contact Reversal	55 (″)		44.5		.19
Cable, Automatic, 60∼ A.C.	137 (″)		114		.17
Cable, Automatic, 60∼ A.C., Full-Wave Differential Amplitude Modulation (After Squier)	396 (″)		330		.16–.17

TABLE OF REACTION TIMES, SIMPLE STIMULI, AFTER BERRY

Type of Stimulus	Time in Seconds		
	Upper	Average	Lower
Visual	0.225	0.187	0.149
Auditory	0.185	0.153	0.120
Tactual	0.190	0.1525	0.115
Olfactory	0.800	0.500	0.200
Pain	1.000	0.700	0.400

CONVERSION TABLE OF FRACTIONAL SIGNAL LENGTHS INTO DECIMAL EQUIVALENTS

10/24	0.416
9/24	0.375
8/24	0.333
7/24	0.291
6/24	0.250
5/24	0.208
4/24	0.166
3/24	0.125
2/24	0.083
1/24	0.041

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